

DESIGN PLAN
FOR
WASTE UNITS 1, 2, 3, 5, 7, 9, 10, 11, 12, 13, 16, AND 17
PROTECCION TECNICA ECOLOGICA, INC.

PRD091 018 622

Submitted to:

Proteccion Tecnica Ecologica, Inc.
Carr. 385 KM 3.5
Penuelas, PR 00624

Submitted by:

OHM Remediation Services Corp.
5335 Triangle Parkway, Suite 450
Norcross, GA 30092

November 1995

Project No. 16139

TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	FACILITY DESCRIPTION	1
2.0	CLOSURE COVER COMPONENTS	2
3.0	STORMWATER CONTROL	3
3.1	STORMWATER GENERATION RATES	3
3.2	STORMWATER DRAINAGE CHANNELS AND CULVERTS	4
3.3	RETENTION AND SEDIMENTATION BASINS	4
3.4	CLOSURE COVER DRAINAGE LAYER	5
4.0	GEOTECHNICAL ANALYSES	9
4.1	GEOMEMBRANE STABILITY	9
4.2	SLOPE CUT STABILITY FOR NATIVE SOIL	9
4.3	SLOPE CUT STABILITY FOR NATIVE ROCK	9
4.4	SETTLEMENT	10
5.0	LANDFILL GAS GENERATION	11

TABLE OF CONTENTS - CONTINUED

- Table 3-1 Drainage Channel Stabilization - Minimum Required RipRap Size
Table 3-2 Stormwater Drainage Channel RipRap Design Criteria and Required Rock Gradation

TABLE OF CONTENTS - CONTINUED

- Appendix A HELP Model Results and Darnage Layer Design
- Appendix B Stormwater Generation Rate Calculations
- Appendix C Stormwater Drainage Channel and Culvert Calculations
- Appendix D Retention and Sediment Basins Design Calculations
- Appendix E Soil Property and Interface Direct Shear Testing Reporty - GeoSynTec Consultants
- Appendix F Laboratory Test Results PROTECO Hazardous Waste Units, Penuelas, Puerto Rico -Caribbean Soil Testing Co. Inc.
- Appendix G Stabilty of Natural and Cut Slopes Adjacent to Buried Waste Units at PROTECO's Waste Disposal Site, Penuelas, Puerto Rico - Geological and Environmental Services
- Appendix H Slope Stability Calculations
- Appendix I Settlement Data for Waste Units 1 and 16
- Appendix J Geomembrane Strength and Stability Calculations
- Appendix K Landfill Gas Generation Calculations

1.0 INTRODUCTION

Proteccion Tecnica Ecologica, Inc. (PROTECO) owns and operates a waste disposal facility in Penuelas, Puerto Rico and is permanently closing Waste Units 1, 2, 3, 5, 9, 10, 11, 12, 13, 16, and 17. This document describes the design process followed for those waste units. The reports, calculations, information, and data contained herein support the Closure and Post Closure Plan, the Construction Specifications, and the Construction Quality Assurance Plan that were prepared for the closure of the waste units listed previously. All these construction documents were prepared in accordance with the United States Environmental Protection Agency (USEPA), the 40 Code of Federal Regulations (CFR) 264, and the Commonwealth of Puerto Rico's Regulation for the Control of Hazardous and Nonhazardous Solid Wastes, Rule 816.

1.1 FACILITY DESCRIPTION

PROTECO's facility is located on the southern side of Puerto Rico approximately 2.5 miles southeast of Penuelas, 2 miles north of Tallaboa Bay of the Caribbean Sea, and 1.5 miles east of the Lower Tallaboa River Valley. The closest community which is approximately 1.5 miles away is Sebouruco. The site occupies approximately 35 acres and is situated in a small valley which elevations range from approximately 260 ft msl to 400 feet msl. The rugged upland terrain of the valley is steep and supports little vegetation. The steep hills which surround the site are covered year round with xerophilous vegetation and are inhospitable to residential, commercial, or agricultural development.

Typical climatic conditions are semiarid with 43 inches of annual precipitation, 88 inches of annual evaporation, 79 degrees Fahrenheit annual average temperature, and predominantly easterly winds off the Caribbean Sea. Most precipitation is lost to run-off due to the hard, impermeable surface soil conditions and steep slopes.

Design of the closure cover system for the Proteccion Tecnica Ecologica, Inc. Waste Units 1, 2, 3, 5, 7, 9, 10, 11, 12, 13, 16, and 17 landfill was accomplished utilizing a number of guidance documents published by the United States Environmental Protection Agency. These documents were utilized in establishing the components of the final cover system and their properties.

2.0 CLOSURE COVER COMPONENTS

The closure cover for all eleven of PROTECO's waste units will be the same and is comprised of seven components of geosynthetic and soil materials to provide an effective barrier to the infiltration of water into the waste. These layers are as follows from the top of the closure cover to the bottom:

- ▶ A Surface Armor Layer consisting of 6 inches of rock and gravel,
- ▶ A Cover Layer consisting of 18 inches of common fill ,
- ▶ A 16 ounces per square yard Nonwoven Geotextile,
- ▶ A 40 mil Thick HDPE Geomembrane,
- ▶ A Low Permeability Layer consisting of 24 inches of soil exhibiting a hydraulic conductivity no greater than 1×10^{-7} cm/s,
- ▶ A Sub-base Layer consisting of varying thicknesses of common fill, and
- ▶ A series of granular inserts with HDPE vent pipes in the top of the closure cover for the collection of landfill gas.

Each of these layers is described in depth in the Construction Specifications and Construction Quality Assurance (CQA) Plan and is depicted in the Project Drawings.

3.0 STORMWATER CONTROL FEATURES

Stormwater control mechanisms were designed as an integral part of the waste units' closure cover system for the PROTECO Facility to prevent stormwater run-on over the closure cover of the waste units and to prevent excessive erosion on the site and surrounding area. Stormwater generation rate calculations were performed utilizing the Rational Method. The stormwater generation rates estimated from these calculations were then used to evaluate the required capacity of the stormwater drainage channels shown on the Project Drawings. Once the size of the drainage channels was chosen , then the size of the riprap to be placed in the drainage channels was chosen.

3.1 STORMWATER GENERATION RATES

The quantity of stormwater which will be directed to each drainage channel was determined by delineating the total area which will direct stormwater to the individual drainage channels. The drainage channels were divided into reaches for the purpose of evaluating the differing flow quantities around each waste unit. Additional reaches were established for drainage channels which serve as collectors for the individual areas. Calculations which were performed to determine the flow rate for each reach are included in Appendix B.

The individual areas in the immediate vicinity of the facility utilized to determine flow quantities to each reach are shown on Sheet C-12 - Drainage Plan of the Project Drawings. In addition to the areas shown on Sheet C-12 there is some stormwater which will flow into the proximity of the surface water control structures from areas to the north and east of the site. These areas are delineated as shown on Figure 1 of this report. The most recent topographic map of the landfill vicinity did not include information on the extent of these areas. To estimate the quantity of stormwater generated from these areas, the Punta Cuchara and Penuelas USGS Quadrangle maps were used to identify the drainage basin. Areas delineated as generating stormwater which will require management were measured utilizing a polar planimeter to determine the total surface area.

In utilizing the Rational Method of determining stormwater generation rates, the C value was used from various sources which are described further in the calculation. In many instances the C value was determined based on a weighted average of varying surface vegetative characteristics and varying surface slope. For each area, the portions of the area with unique slope and cover characteristics were delineated and applied the appropriate weighing factor.

The rainfall intensity utilized in the formula was obtained from Technical Paper No. 42 for Puerto Rico and the Virgin Islands. This source was utilized due to the lack of hydrologic nomographs for the region. Possible sources of these nomographs which were contacted include the Soil Conservation Service in San Juan and Houston, Texas, the National Oceanographic and Atmospheric Administration, the National Climatic Data Center and the USGS.

The design storm event was based on the 100 year, 1 hour rainfall event which resulted in utilizing a rainfall intensity of 5.25 inches per hour.

3.2 STORMWATER DRAINAGE CHANNELS AND CULVERTS

The stormwater flow rates calculated for each drainage area mentioned above was utilized to ensure that adequate capacity is provided by the drainage channels shown on the plans for diverting stormwater away from the waste units and to minimize erosion at the facility. Also, the stormwater flow rates were utilized to calculate the maximum velocity which will be realized during the design storm event to select the proper riprap size for channel protection. Stormwater drainage channel design calculations are included as Appendix C.

Analysis of drainage channel capacity and maximum velocity was accomplished accounting for various vertical slopes and side slopes within the individual reaches shown on Sheet 12 of the Project Drawings. Calculations were performed on each reach at the minimum and maximum slopes to determine the depth of flow and the velocity, respectively. The minimum slope within each reach was evaluated to ensure no overtopping of the drainage channels occur based on the flow generated from the design storm. The maximum slope of each reach was evaluated to determine the flow velocity resulting from the design storm to select riprap of appropriate size. Table 3-1 provides the information utilized to calculate the maximum velocity in each reach and the resulting minimum riprap size.

Riprap sizing was based on Pennsylvania erosion and sediment control standards. See Table 3-2 for graded rock sizes with the corresponding NSA Numbers and maximum permissible velocity.

Culverts have been designed at locations where onsite vehicular traffic must cross the path of drainage channels. Calculations for culvert capacity at these locations are also included in Appendix C.

3.3 RETENTION AND SEDIMENT BASINS

Sedimentation facilities have been provided to serve as final interception devices for sediment laden stormwater prior to allowing any offsite stormwater discharge. There are two basins which will serve this function. One is the existing retention basin, which currently serves as a water source for onsite activities. The other basin has been designed downstream of the majority of the waste units and is proposed to be constructed prior to initiation of construction activities at the landfill. Calculations for these basins are included as Appendix D. No guidance documents from the United States Environmental Protection Agency could be readily attained, thus the guidance utilized for design of the basins was the Manual for Erosion and Sediment Control in Georgia, and the Erosion and Sediment Control Handbook by Goldman, Jackson, and Bursztynsky..

The existing retention basin, with modifications as shown on the closure plan, located

adjacent to Waste Unit 5 was evaluated to verify that adequate sediment storage capacity is available in this basin for sediment laden stormwater directed to the basin. Also, the surface area of the basin was checked to ensure adequate settling properties for the sediment laden stormwater.

The sediment basin located between the entrance road and the maintenance facility was designed to prevent offsite sediment migration from the remainder of the area which will be disturbed by closure activities. Sediment generation rates and required cleaning frequencies were calculated for both the construction period and the post closure period. These calculations have also been included in Appendix D.

3.4 CLOSURE COVER DRAINAGE LAYER

The computer model entitled, Hydraulic Evaluation of Landfill Performance (HELP) version 2.05 issued by the USEPA was used to analyze the amount of precipitation that would run-off from the closure cover as well as infiltrate into the closure cover. The program contains standard climatic information for the area and has the ability to accept actual site information. Five years of rainfall data collected at the site was used in the analysis.

The analyses were performed on Waste Unit 1. Waste Unit 1 is considered the worst case scenario because the conditions modeled were for the thinnest section of closure cover and the flattest geomembrane slope. The cross section that was used for the analysis is described in Section 1.3. The input and output data that was used for the analyses are included in Appendix A. For ease and uniformity of construction all the lateral drainage layers for waste units will be designed and constructed for the conditions modeled.

The calculations were performed to verify that less than one foot of water head would accumulate on the top of the geomembrane. The water run-off volume calculated was used in the sizing of the drainage channels surrounding the waste units and the infiltration calculated is used in the choice of the nonwoven geotextile which serves partly as a lateral drainage layer.

The results of the HELP analysis indicate that the closure cover design maintains a head of 0.0289 inches as a peak daily value which is less than one foot of head over the geomembrane as required by the regulations.

The slope of the geomembrane ranges from 3 to 8 percent. Because the Surface Armor Layer was designed to have a maximum slope of 5 percent, the thickness of the Cover Layer varies to compensate for the slopes steeper than 5 percent. There are two benefits to this design. One is the increased slope on the geomembrane provides greater water flow capacity in the nonwoven geotextile, resulting in a lower head on the geomembrane than would be realized by maintaining a 5 percent slope for the geomembrane. The other benefit is an increased thickness in the Cover Layer which will provide a thicker buffer between the surface of the waste units' closure cover, the nonwoven geotextile, and the geomembrane of

the closure cover. The increased thickness provides protection from burrowing animals damaging the water retardant layers of the final cover system.

Table 3-1 - Drainage Channel Stabilization Minimum Size of Riprap

<i>Reach Identifier</i>	<i>Maximum Slope (%)</i>	<i>Side Slope (H:V)</i>	<i>Flow Rate (cfs)</i>	<i>Velocity (ft/sec)</i>	<i>Rip Rap Size (NSA No.)</i>
A	8	8:1	19.1	6.8	R-4
B	8	5:1	25.2	6.4	R-4
C	7.1	10:1	44.3	6.2	R-4
D	13.3	2:1	47.9	10.9	R-5
E	11.8	2.5:1	0.9	2.6	R-2
F	20	2:1	18	9.2	R-5
F-1	6.7	2:1	18	5.3	R-4
G	14.3	2:1	37.4	9.7	R-5
H	16.7	3.5:1	23.6	8.8	R-4
I	11.8	4:1	55.7	9.6	R-5
J	40	1:1	79.3	14.4	R-7
K	33	2:1	39	11.8	R-6
L	7.1	2.5:1	311	11.3	R-6
Existing Ditch "B"	2.9	4:1	39	5.3	R-3

TABLE 3.2
STORMWATER DRAINAGE SWALE
RIPRAP DESIGN CRITERIA AND
REQUIRED ROCK GRADATION

SEA NO.	Graded Rock Size (In.)			Permissible velocity-fps*	n^{**}
	Max.	D_{50}	Min.		
R-1	1.5	.75	No. 8	2.5	0.025
R-2	3	1.50	1	4.5	0.028
R-3	6	3	2	6.5	0.031
R-4	12	6	3	9.0	0.035
R-5	18	9	5	11.5	0.038
R-6	24	12	7	13.0	0.0395
R-7	30	15	12	14.5	0.041

* Permissible velocities based on rock at 165 lbs. per cubic foot. Adjust velocities for other rock weights used. See Figure 4.6.

TABLE 4.7d Maximum Permissible Velocities for Reno Mattress and Gabions				
Type	n	Thickness inches	Rock fill Gradation-in.	Permissible Velocity-fps
Reno Mattress	.025	6	3 - 6	13.5
	.025	9	3 - 6	15.0
	.025	12	4 - 6	18.0
Gabion	.027	18 +	5 - 9	22.0

* Permissible velocities may be increased by the introduction of sand mastic grout. Refer to manufacturer's recommendations/specifications for permissible velocities.

$$** n = 0.0395 (d_{50})^{1/6}$$

Ref. → Erosion and Sediment Control Handbook

p. 4.21, by Goldman, Jackson, & Burzstynsky
McGraw Hill 1986

4.0 GEOTECHNICAL ANALYSES

Geotechnical analyses were performed on the final cover and other areas in the vicinity of the landfill which required further evaluation to ensure adequate stability of slopes are maintained. These analyses include the following calculations:

- ▶ The slope stability of the interface between the geomembrane and the low permeability material,
- ▶ The stability of the 2:1 slopes which will be constructed as part of the closure,
- ▶ The stability of the vertical face adjacent to the existing drainage ditch along the eastern portion of the site, and
- ▶ The potential settlement of the waste units.

4.1 GEOMEMBRANE STABILITY

Smooth surfaced geomembrane commonly has a low interface frictional resistance and usually is a controlling factor in the stability of the overlying materials. The interface frictional resistances for all components of the closure cover were identified to determine which interface would be the controlling interface. An analysis was performed on the interface of geomembrane and geotextile which was identified as the layer interface likely to fail first. The results of this analysis indicates that the interface friction between the geomembrane and the geotextile is acceptable for constructing the closure cover as shown on the Construction Drawings and required by the Technical Specifications. The report prepared which demonstrates the stability is included as Appendix J.

4.2 SLOPE CUT STABILITY FOR NATIVE SOIL

The area surrounding the facility contains hills that will have to be cut at slopes greater than the existing conditions. These slopes will not be constructed by placing of a controlled fill material and therefore compaction, moisture content, and strength of the earth slopes will can not be monitored. To estimate the existing conditions slope stability analyses were performed to determine what maximum slope that could be used for design. A field and laboratory investigation was performed which produced site soil characteristics and parameters. This information was used in the slope stability analyses. The results of the analyses performed indicates that slopes constructed as steep as 2:1 having the soil characteristics tested will remain stable. These recommendations and all information are contained in the report entitled "*Laboratory Test Results, PROTECO Hazardous Waste Units, Penuelas, Puerto Rico*" dated August 9, 1994 prepared by Caribbean Soil Testing, Inc. included as Appendix F.

4.3 SLOPE CUT STABILITY FOR NATIVE ROCK

In addition to the native soil slopes that will have cuts in them, the hills surrounding the

facility will have rock slopes for the construction. To address these rock stability concerns a geotechnical report entitled "*Stability of Natural and Cut-Slope Adjacent to Buried Waste Units at PROTECO's Disposal Site , Penuelas, Puerto Rico*" dated September 1994 was prepared by Geological Engineering and Environmental Services. The report is included in Appendix G. The report confirms the stability of vertical cuts in the material at the site. However, the report mentions specifically for drainage ditches cut into rock that there is the possibility of small failures within the slope and recommends that measures be taken to provide continuous flow through the drainage ditches by constructing rock drains in the ditch.

Although this would provide a continuous flow, even in the event of a minor slump, the existing capacity of the ditch would be reduced by constructing the rock drain in the ditch. Rather than adversely affecting the existing crystalline surface of the ditch by performing construction activities in the ditch, the design capacities of the drainage channels down slope of the existing ditch provide ample capacity to divert any stormwater runoff which may be diverted due to a slump.

4.4 SETTLEMENT

Settlement tests were conducted at Waste Units Nos. 1 and 16. The results of these tests reveal that the potential settlement at the landfill is 0.017 feet and 0.023 feet in a two month period for Waste Units 1 and 16, respectively. The grades of the closure cover are designed to provide positive drainage of the closure cover throughout the life of the waste units. The settlement data is included in Appendix I. Calculations that were performed to ascertain the durability of the geomembrane during settlement have been performed. These calculations indicate that the geomembrane will fulfill the design strength conditions and not fail. The calculations for geomembrane settlement are included as Appendix J.

5.0 LANDFILL GAS GENERATION

Municipal landfills that contain organic materials will generate methane gas from the decay of the organic material. The gas will escape from the landfill and migrate via the path of least resistance to the atmosphere. The usual path of least resistance is up, but with the installation of a closure cover, the low permeability layer will force the gas to find new pathways which may harmful to the surroundings. Therefore an estimate of the gas that may be generated from the waste units has been performed by a method proposed by Bagchi. This method will likely produce a conservative estimate of the gas generation rate for the waste units due to the age of the landfill and the fact that the landfill contains little to no municipal waste.

According to Koerner, hazardous waste landfills produce little landfill gas and therefore require no gas collections systems or low capacity systems. The calculations for the estimate of methane gas generation are included in Appendix K. The gas generation rate was than used in the design of the gas collection areas and the gas venting of the closure cover.

APPENDIX A

"HELP" MODEL RESULTS AND DRAINAGE LAYER DESIGN

**PROTECO - WASTE UNITS 1,2,3,5,9,10,11,12,13,16,&17
PENUELAS, PUERTO RICO
NOVEMBER 15, 1995**

BARE GROUND

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	= 6.00 INCHES
POROSITY	= 0.4170 VOL/VOL
FIELD CAPACITY	= 0.0454 VOL/VOL
WILTING POINT	= 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	= 0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	= 0.00999999776 CM/SEC

LAYER 2

VERTICAL PERCOLATION LAYER

THICKNESS	= 18.00 INCHES
POROSITY	= 0.4224 VOL/VOL
FIELD CAPACITY	= 0.3495 VOL/VOL
WILTING POINT	= 0.2648 VOL/VOL
INITIAL SOIL WATER CONTENT	= 0.3495 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	= 0.000000850000 CM/SEC

LAYER 3

LATERAL DRAINAGE LAYER

THICKNESS	= 0.15 INCHES
POROSITY	= 0.8000 VOL/VOL
FIELD CAPACITY	= 0.0300 VOL/VOL
WILTING POINT	= 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	= 0.0300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	= 0.569999992847 CM/SEC
SLOPE	= 5.00 PERCENT
DRAINAGE LENGTH	= 385.0 FEET

LAYER 4

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	= 24.00 INCHES
POROSITY	= 0.4300 VOL/VOL
FIELD CAPACITY	= 0.3663 VOL/VOL
WILTING POINT	= 0.2802 VOL/VOL
INITIAL SOIL WATER CONTENT	= 0.4300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	= 0.000000100000 CM/SEC
LINER LEAKAGE FRACTION	= 0.01000000

LAYER 5

VERTICAL PERCOLATION LAYER

THICKNESS	= 240.00 INCHES
POROSITY	= 0.5200 VOL/VOL
FIELD CAPACITY	= 0.2942 VOL/VOL
WILTING POINT	= 0.1400 VOL/VOL
INITIAL SOIL WATER CONTENT	= 0.1969 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	= 0.00019999995 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	= 72.60
TOTAL AREA OF COVER	= 43560. SQ FT
EVAPORATIVE ZONE DEPTH	= 10.00 INCHES
UPPER LIMIT VEG. STORAGE	= 4.1916 INCHES
INITIAL VEG. STORAGE	= 1.6443 INCHES
INITIAL SNOW WATER CONTENT	= 0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN SOIL AND WASTE LAYERS	= 64.1371 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
SOLAR RADIATION FOR SAN JUAN PUERTO RICO

MAXIMUM LEAF AREA INDEX	= 0.00
START OF GROWING SEASON (JULIAN DATE)	= 0
END OF GROWING SEASON (JULIAN DATE)	= 367

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
76.50	76.60	77.50	78.80	80.30	81.70
82.00	82.20	81.90	81.40	79.60	77.70

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1989 THROUGH 1993

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
---------	---------	---------	---------	---------	---------

PRECIPITATION

TOTALS					
3.55	2.24	3.25	4.57	5.60	3.74
1.64	4.79	8.07	11.09	4.60	1.99
STD. DEVIATIONS					
4.36	1.68	3.64	2.55	5.22	2.00
1.13	1.26	4.26	7.72	3.45	1.75

RUNOFF

TOTALS					
1.723	0.091	0.649	0.397	2.475	0.891
0.058	0.438	2.480	5.786	1.360	0.090
STD. DEVIATIONS					
3.210	0.084	1.393	0.607	3.363	0.775
0.052	0.482	3.176	6.867	2.218	0.122

EVAPOTRANSPIRATION

TOTALS					
1.178	1.901	1.723	2.838	2.995	2.295
1.389	3.047	4.184	3.836	3.166	1.468
STD. DEVIATIONS					
0.763	1.133	1.166	1.180	1.777	0.860
0.903	0.857	1.449	1.312	0.484	1.041

LATERAL DRAINAGE FROM LAYER 3

TOTALS					
0.6477	0.4577	0.4876	0.5862	0.8209	0.6693
0.5954	0.5891	0.7191	0.8765	0.8661	0.8798

STD. DEVIATIONS

0.2938	0.3061	0.3072	0.2862	0.1328	0.2007
0.3933	0.3471	0.1280	0.0326	0.0005	0.0344

PERCOLATION FROM LAYER 4**TOTALS**

0.0011	0.0010	0.0011	0.0010	0.0011	0.0010
0.0011	0.0011	0.0010	0.0011	0.0010	0.0011

STD. DEVIATIONS

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION FROM LAYER 5**TOTALS**

0.0009	0.0008	0.0009	0.0009	0.0009	0.0009
0.0009	0.0009	0.0009	0.0009	0.0009	0.0009

STD. DEVIATIONS

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1993

	INCHES	CU. FT.	PERCENT
PRECIPITATION	55.11	200057	100.00
RUNOFF	16.438	59671.	29.83
EVAPOTRANSPIRATION	30.019	108969.	54.47
LATERAL DRAINAGE FROM LAYER 3	8.1954	29749.	14.87
PERCOLATION FROM LAYER 4	0.0125	45.	0.02
PERCOLATION FROM LAYER 5	0.0106	38	0.02
CHANGE IN WATER STORAGE	0.449	1629.	0.81

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1993

	INCHES	CU. FT.
PRECIPITATION	8.96	32524.8
RUNOFF	6.906	5070.3
LATERAL DRAINAGE FROM LAYER 3	0.0289	104.8
PERCOLATION FROM LAYER 4	0.0000	0.1
HEAD ON LAYER 4	0.1	
PERCOLATION FROM LAYER 5	0.0000	0.1
SNOW WATER	0.00	0.0
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4192
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.1161

FINAL WATER STORAGE AT END OF YEAR 1993

LAYER	INCHES	(VOL/VOL)
1	2.01	0.3342
2	7.60	0.4223
3	0.06	0.3841
4	10.32	0.4300
5	47.26	0.1969
SNOW WATER	0.00	



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 1 of

Proj. No.	Client	Location	Subject
16139	Protoco	Ponceles Puerto Rico	Drainage Layer Design
Preparer's Initials JEB	Date 11/13/95	Reviewer's Initials JKO	Date 11/13/95 Approver's Initials Date

The Hydrogeologic Evaluation of Landfill Performance (HELP) model was used to estimate the volume of water to be collected and discharged through the drainage layer (16oz geotextile).

Basis for selecting 16 oz non woven geotextile as drainage layer in the closure cover of the waste units.

1) For Ponceles Area of Puerto Rico

- a) Average Rainfall is Approx 50 in./year
- b) Average Evapotranspiration Rate is Approx 30 inches/year

2) HELP Model Calculation are based on

- a) Daily rainfall data for Ponceles for years 1980-1993
- b) Evapotranspiration for San Juan, Puerto Rico which is approx 30 inches/year.

3) From Help model dated November 13, 1995;

Based on 1 acre/ceep cover for units 9, 10, 11, 12, & 16;

Peak Daily Volume	Area	Drainage area	Avg slope
104.8 ft ³	43,560 ft ²	3825 ft	5%

Peak daily volume = ✓

Determine transmissivity, Θ , required

$$\theta = \frac{V}{t \cdot l} = \frac{104.8 \text{ ft}^3}{(1 \text{ day})(3825 \text{ ft})} \left(\frac{1 \text{ day}}{24 \text{ hr}} \right) \left(\frac{1 \text{ hr}}{60 \text{ min}} \right)$$

$$\theta = 1.9 \times 10^{-4} \frac{\text{ft}^3}{\text{min} \cdot \text{ft}} \checkmark$$

$$\Theta_{reqd} = Kt = \frac{\theta}{i} \quad \text{where } i = 1 \text{ ft (unit basis)} \\ i = \text{flow gradient} = 5\%$$

$$\Theta_{reqd} = \frac{1.9 \times 10^{-4} \text{ ft}^3/\text{min} \cdot \text{ft}}{(0.05)(1 \text{ ft})}$$

$$\Theta_{reqd} = 3.8 \times 10^{-5} \text{ ft}^3/\text{min} \cdot \text{ft} \checkmark$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 2 of _____

Proj. No.	Client	Location	Subject
16139	PROTECO	Pentelco Rock L.	Drainage Layer Design
Preparer's Initials	Date	Reviewer's Initials	Approver's Initials

Estimate normal stress on drainage layer

$$J_n = \gamma h$$

$$\gamma = \text{Unit wt of soil} = 110 \text{ psf}$$

$h = 2 \text{ ft thick top cover layer}$

$$J_n = (2 \text{ ft})(110 \text{ lb/ft}^3)$$

$$J_n = \underline{\underline{220 \text{ lb/ft}^2}} \checkmark$$

See figure 212 (attached)

For Tractive 1150 (16 oz) @ $J_n = 220 \text{ psf}$

$$\Theta_{\text{actual}} = 14.5 \times 10^{-3} \frac{\text{ft}^3}{\text{min-ft}}$$

$$FS = \frac{\Theta_{\text{actual}}}{\Theta_{\text{reqd}}} = \frac{14.5 \times 10^{-3} (\text{ft}^3)}{3.8 \times 10^{-3} (\text{min-ft})} = \underline{\underline{3.8}} \checkmark$$

The one core area over units 9, 10, 11, 12, & 16 was closed as a worst case scenario since it has the longest flowpath at an average slope of 5%.

Check @ road (for $V = 104.8 \text{ ft}^3$ for slope of 4% : 8%)

$$At_i = 470 \quad L = 210 \text{ ft}$$

$$q = \frac{104.8 \text{ ft}^3}{(1 \text{ day})(210 \text{ ft})} \left(\frac{1 \text{ min}}{24 \text{ hr}} \right) \left(\frac{1 \text{ hr}}{60 \text{ min}} \right) \quad q = 3.5 \times 10^{-4} \frac{\text{ft}^3}{\text{min-ft}} \checkmark$$

$$\Theta_{\text{reqd}} = \frac{3.5 \times 10^{-4} \text{ ft}^3/\text{min-ft}}{(0.04)(1 \text{ ft})} = 8.75 \times 10^{-3} \frac{\text{ft}^3}{\text{min-ft}} \checkmark$$

$$F.S. = \frac{14.5 \times 10^{-3} (\text{ft}^3)}{8.75 \times 10^{-3} (\text{min-ft})} = \underline{\underline{1.7}} \checkmark$$



COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

OHM Corporation

Page 3 of _____

Proj. No. 16139	Client PROTICO	Location Ponce, Puerto Rico	Subject Draining Layer Design
Preparer's Initials JES	Date 11/13/95	Reviewer's Initials JKO	Date 11/13/95

At $i = 8\%$ and $L = 130\text{ft}$

$$q = \frac{104.8 \text{ ft}^3}{(1 \text{ day})(130 \text{ ft})} = 5.6 \times 10^{-4} \frac{\text{ft}^3}{\text{ft} \cdot \text{min}} \checkmark$$

$$\Theta_{\text{reqd}} = \frac{5.6 \times 10^{-4} \text{ ft}^3/\text{min-ft}}{(0.087)(1)} = 7.0 \times 10^{-3} \frac{\text{ft}^3}{\text{min-ft}} \checkmark$$

$$FS. = \frac{14.5 \times 10^{-3}}{7.0 \times 10^{-3}} \left(\frac{\text{ft}^3}{\text{min-ft}} \right) = \underline{\underline{2.1}} \checkmark$$

Thus, using Trevira 1150-160 geotextile will provide adequate transmissivity for all waste units.



OHM Remediation
Services Corp.

COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 5 of _____

Proj. No. <u>18146</u>	Client <u>PROTECO</u>	Location <u>PENELAS, PR</u>	Subject <u>GEOTEXTILE DRAIN</u>		
Preparer's Initials <u>JKo</u>	Date <u>10/4/85</u>	Reviewer's Initials	Date	Approver's Initials	Date

SOLUTION

DETERMINIVE AOS REQUIRED TO PREVENT
SOIL LOSS. FROM KOERNER

Method I

$$\begin{aligned} \leq 50\% \text{ passing } \#200 & \text{ Then } AOS \geq \#30 \\ \geq 50\% \text{ passing } \#200 & \text{ Then } AOS \geq \#50 \end{aligned}$$

Method II

$$O_{35} \leq (2 \text{ or } 3) d_{85} \quad d_{85} = 0.04.$$

$$O_{35} \leq 2(.04) \text{ or } 3(.04)$$

$$O_{35} \leq 0.08 \text{ or } .12$$

$$\#200 \text{ or } \#140$$

NOT POSSIBLE

Therefore AOS Should be between
in #30 and #140



OHM Remediation
Services Corp.

COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 4 of _____

Proj. No. <u>1814</u>	Client <u>PROTECO</u>	Location <u>PENELAS, PR</u>	Subject <u>GEOTEXTILE DRAIN</u>		
Preparer's Initials <u>JK</u>	Date <u>10/4/85</u>	Reviewer's Initials	Date	Approver's Initials	Date

SOLUTION

DETERMINE AOS REQUIRED TO PREVENT
SOIL LOSS. FROM KOERNER

Method I

$$\begin{aligned} \leq 50\% \text{ passing } \#200 & \text{ Then } AOS \geq \#30 \\ \geq 50\% \text{ passing } \#200 & \text{ Then } AOS \geq \#50 \end{aligned}$$

Method II

$$O_{95} \leq (2 \text{ or } 3) d_{85} \quad d_{85} = 0.04$$

$$O_{95} \leq 2(0.04) \text{ or } 3(0.04)$$

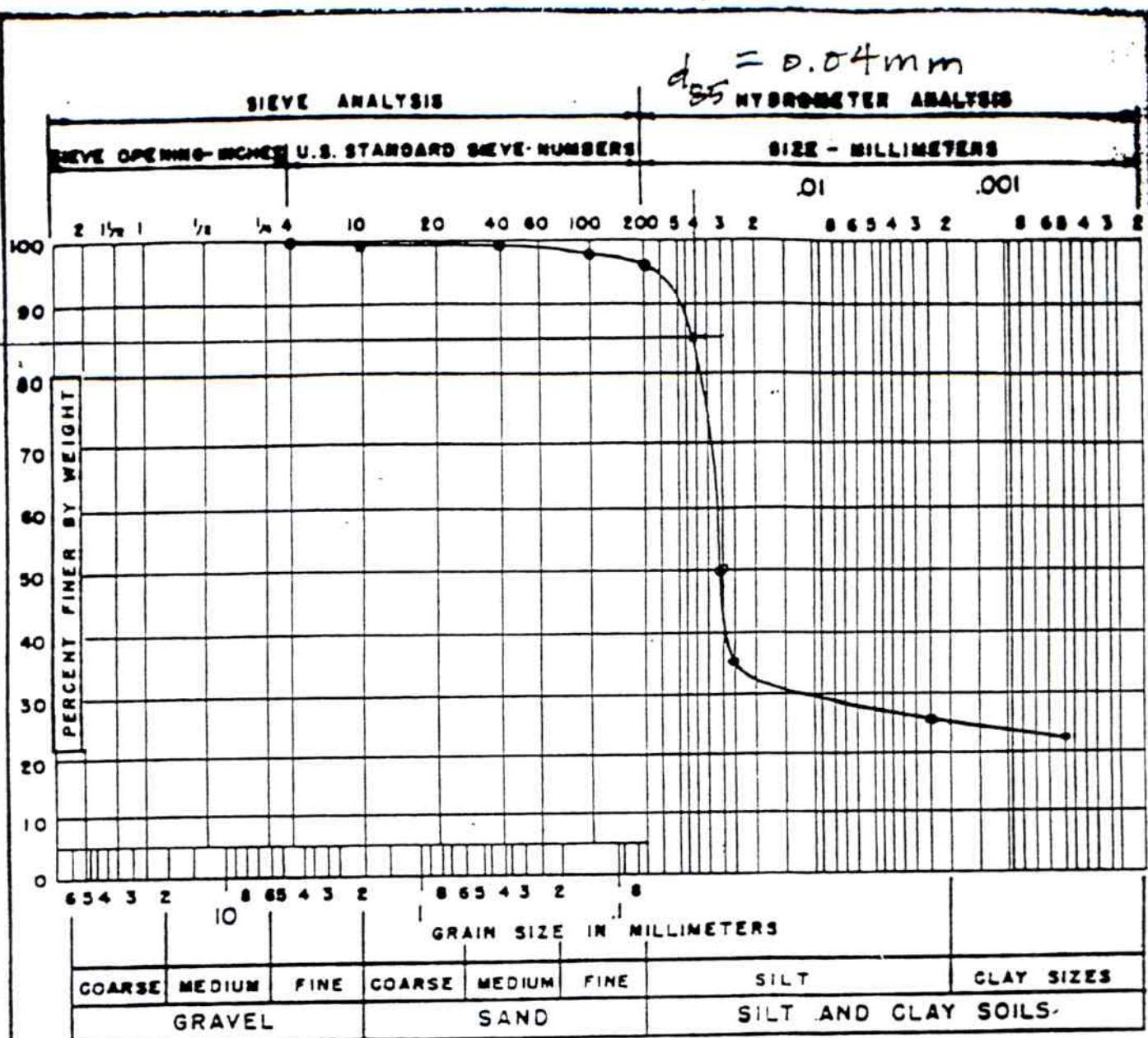
$$O_{95} \leq 0.08 \text{ or } .12$$

$$\cancel{\#200} \text{ or } \#140$$

NOT POSSIBLE

Therefore AOS Should be between
a #30 and #140

REPRESENTATIVE VEGETATIVE COVER



CURNO.	SYM.	SAMPLE NUMBER	DEPTH	ELEV.	L.L.	P.I.	DESCRIPTION
1		GT-3	13'-15'		75.5	480	

PROTECO

GRAIN SIZE DISTRIBUTION

CARIBBEAN SOIL TESTING CO., INC.
Consulting Engineers, Hato Rey, P.R.

BY:

DATE: 8/02/94

DWG. J.J.R.Q.

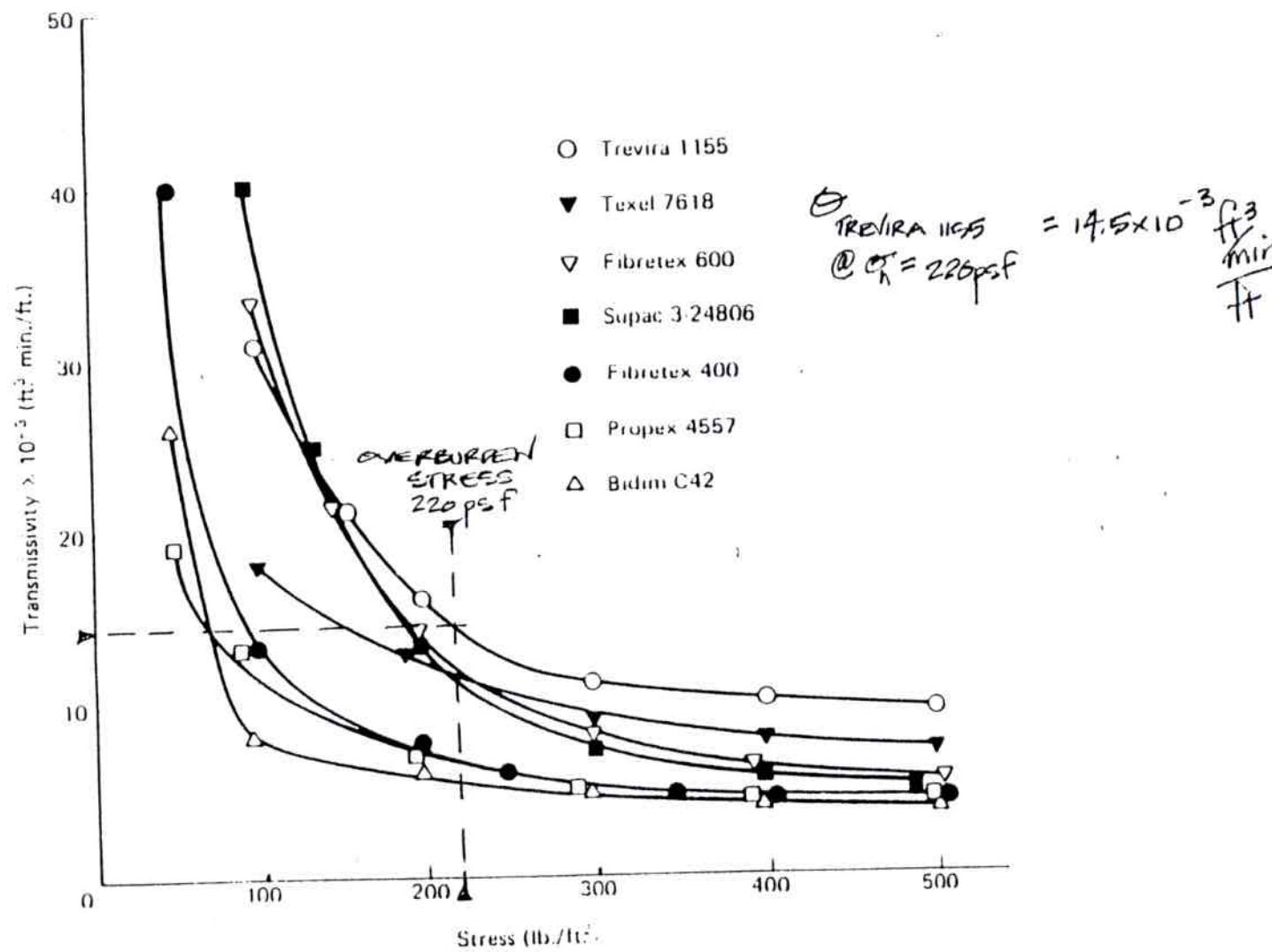


Figure 2.12 Transmissivity response versus applied normal stress for various needle-punched nonwoven geotextiles (after Koerner, et al. [23])

This test, developed by the New York Department of Transportation, is aimed at the reduction in turbidity of rivers and streams during adjacent construction activities.

2.2.4.8 Soil Retention: Silt Fences

A second variation of a soil retention test is directed toward the use of geotextiles

TRANSMISSIVITY CALCULATION

230

FOR GEOTEXTILE Designing with Geotextiles Chap. 2

Sec. 2

where

θ = the transmissivity.

k_p = the in-plane permeability coefficient (hydraulic conductivity), and

t = the thickness.

The relationship will appear as $\theta = kt$, the k being understood to be in-plane permeability. Transmissivity will be used in conjunction with Darcy's formula under the assumption that laminar flow exists within the geotextile. This is generally valid, but when very thick geotextiles are used together with high hydraulic gradients, the assumption of a laminar flow regime must be challenged. Indeed, with the geonets and drainage geocomposites discussed in Chapters 4 and 6, flow is generally turbulent and Darcy's formula cannot be used. A different approach to the design of geonets and drainage geocomposites will be taken from that used in this section.

2.9.3 Gravity Drainage Design

For gravity drainage problems involving liquid flow in geotextiles, the driving force is merely the slope at which the geotextile is placed. Using the geometry of the particular situation under consideration, a required transmissivity can be calculated using Darcy's formula. This value is then compared to the allowable transmissivity of the candidate geotextile for calculation of a factor of safety. Depending on the severity of the situation, these values of factor of safety should be quite high, depending on how the allowable transmissivity is obtained (recall Equation 2.19 and Table 2.13).

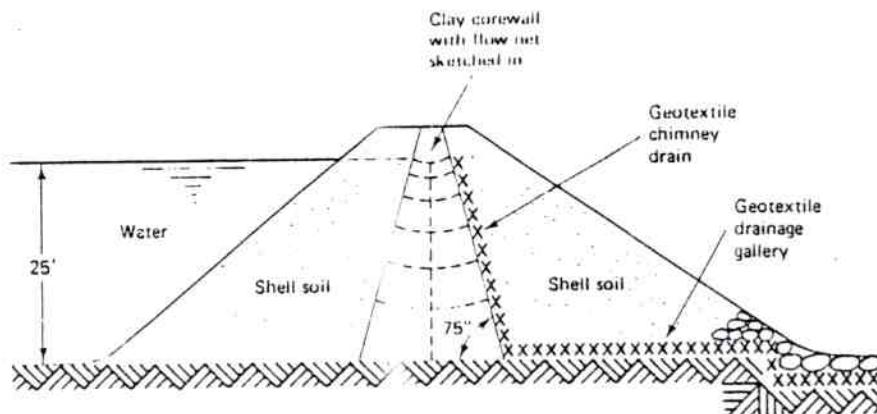
Note should also be made that the allowable geotextile's transmissivity is that value at the normal stress which is acting upon it. This is usually calculated on the basis of the effective stress of the soil placed above it if the geotextile is horizontal. If the geotextile is vertical, the normal stress is the vertical effective stress times the appropriate coefficient of earth pressure. This can usually be taken as the at-rest value, and the relationship $K_o = 1 - \sin \phi$ is often used. If the friction angle of the soil (ϕ) is not known, K_o can be taken approximately equal to 0.5. It should be recalled from the testing section involving hydraulic properties (Section 2.2.4.6) that the transmissivity decreases strongly with applied normal stress on the fabric. Figure 2.12 illustrated this behavior for a number of commercially available nonwoven needle-punched geotextiles. Note that a constant value of transmissivity is reached above approximately 400 lb./ft.² (19 kPa). For needle-punched nonwoven geotextiles in the range 10 to 20 oz./yd.² (34 to 68 g/m²), the transmissivity under stresses greater than 400 lb./ft.² (19 kPa) is in the range 0.004 to 0.010 ft.³/min.-ft. (0.00037 to 0.00093 m³/min.-m).

The following example illustrates the use of these concepts.

Example:

Given a 25-ft. high zoned earth dam for use as an irrigation reservoir. The dam has a cross section as shown below. A nonwoven needle-punched geotextile is being considered as a chimney drain and drainage gallery. The geotextile under consideration is a 12-oz./yd.²

needle-punched nonwoven fabric with $\theta_{allow} = 0.0045 \text{ ft.}^3/\text{min.-ft.}$ at normal stresses greater than 400 lb./ft.^2 . What factor of safety does this geotextile have for the amount of flow seeping through the core wall, which is a clayey silt of permeability $2.0 \times 10^{-5} \text{ ft./min.}$ ($= 10^{-5} \text{ cm/s}$)?



Solution: In stages, the solution is as follows:

(a) Calculate the maximum seepage coming through the clay core wall that the geotextile must carry. Use of a flow net (as shown in the sketch) gives

$$\begin{aligned} q &= kh \left(\frac{6}{2} \right) \\ &= (2 \times 10^{-5}) (25) \left(\frac{6}{2} \right) \\ &= 1.50 \times 10^{-3} \text{ ft.}^3/\text{min.-ft. dam} \end{aligned}$$

(b) Calculate the gradient of flow in the geotextile.

$$\begin{aligned} i &= \sin 75^\circ \\ &= 0.97 \end{aligned}$$

(c) Calculate the required transmissivity, θ_{reqd} , using Darcy's formula.

$$\begin{aligned} q &= kiA \\ &= kt(i \times w) \\ &= (kt)(i \times w) \end{aligned}$$

$$\begin{aligned} kt &= \frac{q}{i \times w} \\ \theta_{reqd} &= \frac{1.50 \times 10^{-3}}{(0.97)(1.00)} \\ &= 1.55 \times 10^{-3} \\ &= 0.0015 \text{ ft.}^3/\text{min.-ft. fabric} \end{aligned}$$

(d) Determine the factor of safety.

$$\begin{aligned} FS &= \frac{\theta_{\text{allow}}}{\theta_{\text{reqd}}} \\ &= \frac{0.0015}{0.00015} \\ &= 3.0 \end{aligned}$$

Due to the critical nature of this application, this FS value is too low and a minimum value of 5.0 is recommended. Two options present themselves: one is to use two layers of fabric in the lower part of the chimney drain and in the drainage gallery (the upper part of the chimney drain could still use one layer); the other is to use the $FS = 5.0$ and calculate the necessary geotextile's transmissivity.

$$\begin{aligned} \theta &= \theta_{\text{reqd}} \times FS \\ &= 0.00015 \times 5.0 \\ &= 0.00075 \text{ ft.}^3/\text{min. ft.} \end{aligned}$$

and use a fabric with this allowable capacity. Recall the transmissivity curves of Figure 2.12.

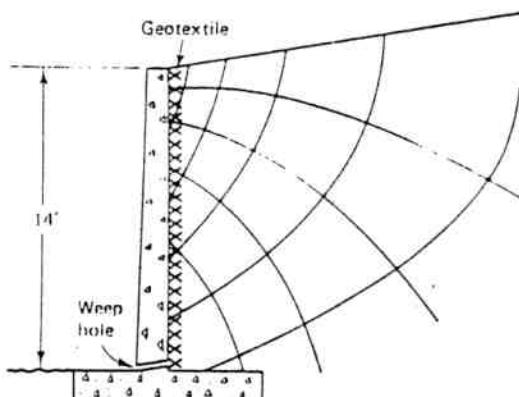
(e) One must now do a soil retention analysis to see that soil particles do not embed in the geotextile and decrease its transmissivity. The analysis is the same as in Section 2.8.

(f) Finally, concern for long term soil-geotextile compatibility must be addressed. Here within an earth dam is where long-term flow tests or gradient ratio tests have applicability. See Sections 2.2.5.4 and 2.2.5.5 for details.

As the next example shows, however, the amount of flow that geotextiles can handle is limited to specific situations.

Example:

Calculate the number of fabric layers required to drain water from behind the following concrete cantilever retaining wall if each layer has a transmissivity of $\theta_{\text{allow}} = 0.011 \text{ ft.}^3/\text{min.-ft. fabric}$. The soil backfill is a silty sand (ML-SW) with $k = 0.098 \text{ ft./min.}$



Sec. 2.9 Designing for Drainage

Solution: As before, we proceed in parts:

(a) Calculate the maximum flow rate coming to the geotextile. From the flow net above, we have

$$\begin{aligned} q &= kh \left(\frac{F}{N} \right) \\ &= (0.098) (14) \left(\frac{5}{5} \right) \\ &= 0.14 \text{ ft.}^3/\text{min.-ft. wall} \end{aligned}$$

(b) Determine the flow gradient within the geotextile.

$$\begin{aligned} i &= \tan 90^\circ \\ &= 1.0 \end{aligned}$$

(c) Calculate the required transmissivity.

$$\begin{aligned} q &= kiA \\ &= ki (t \times w) \\ &= (kt) (i \times w) \end{aligned}$$

$$\begin{aligned} \theta_{\text{reqd}} &= kt = \frac{q}{i \times w} \\ &= \frac{0.14}{1.0 \times 1.0} \\ \theta_{\text{reqd}} &= 0.14 \text{ ft.}^3/\text{min.-ft. wall} \end{aligned}$$

(d) Compare this value to the actual geotextile's transmissivity to obtain a factor of safety.

$$\begin{aligned} FS &= \frac{\theta_{\text{allow}}}{\theta_{\text{reqd}}} \\ &= \frac{0.011}{0.14} \\ &= 0.078 \quad \text{No good!} \end{aligned}$$

(e) Calculate the number of geotextile layers required to handle $0.14 \text{ ft.}^3/\text{min.-ft. wall}$ under the assumptions that multiple layers linearly increase transmissivity (they do not) and $FS = 1.0$ (very poor practice).

$$\begin{aligned} \text{Numbers of layers} &= \frac{0.14}{0.011} \\ &= 13 \quad \text{Wow!} \end{aligned}$$

Easily seen is that this application is not suited for geotextiles. It is, however, a perfect situation for geonets or drainage geocomposites, which have much greater in-plane flow capacity. Geonets are the subject of Chapter 4, and geocomposites are the subject of Chapter 6.

SOIL RETENTION FOR GEOTEXTILE

Sec. 2.4 Geotextile Functions and Mechanisms

121

offer a practical remedy to many problems involving the flow of liquids.

2.4.3.1 Permeability

This particular discussion of fabric permeability refers to cross plane permeability when liquid flow is perpendicular to the plane of the fabric. Some of the fabrics used for this purpose are relatively thick and compressible. For this reason the thickness is included in the permeability coefficient and is used as a "permittivity," which was previously defined as

$$\Psi = \frac{k_n}{t} \quad (2.9)$$

where

Ψ = the permittivity,
 k_n = the cross-plane permeability coefficient, and
 t = the thickness at a specified normal pressure.

Uarvelas Layer

The testing for geotextile permittivity was covered in Section 2.2.4.4.

2.4.3.2 Soil Retention

As one allows for greater flow of water through the geotextile, the void spaces in it must be made larger. There is, however, a limit—that being when the upstream soil particles start to pass through the fabric voids along with the flowing liquid. This leads to an unacceptable situation called "soil piping," in which the finer soil particles are carried through the fabric, leaving larger soil voids behind. The liquid velocity then increases, accelerating the process, until the soil structure begins to collapse. This collapse often leads to minute sinkhole-type patterns that grow larger with time.

This entire process is prevented by making the geotextile voids small enough to retain the soil on the upstream side of the fabric. It is the coarser soil fraction that must be initially retained; this is the targeted soil size in the design process. These eventually block the finer sized particles. Fortunately, filtration concepts are well established in the design of soil filters, and those same ideas will be used to design an adequate geotextile filter.

There are a number of approaches to accomplishing soil retention, all of which use the soil particle size characteristics and compare them to the 0_{95} size (as determined by the AOS test) of the fabric. The simplest of these methods examines the percentage of soil passing the No. 200 sieve (-0.074 mm). According to Task Force 25, the following is recommended [40]:

1. Soil $\leq 50\%$ passing the No. 200 sieve
AOS of the fabric \geq No. 30 sieve (i.e., $0_{95} < 0.59$ mm)
2. Soil $> 50\%$ passing the No. 200 sieve
AOS of the fabric \geq No. 50 sieve (i.e., $0_{95} < 0.297$ mm)

Slightly more restrictive is the recommendation of Carroll for the $d_{0.5}$ size in millimeters, which is the following [41]:

$$d_{0.5} < (2 \text{ or } 3) d_{50} \quad (2.22)$$

where d_{50} is the particle size in millimeters for which 50% of sample is finer. Finally, the most conservative method is after Giroud [42], who presents a table for recommended $d_{0.5}$ values (i.e., the opening size in millimeters corresponding to the AOS value) in terms of relative density (D_R), coefficient of uniformity (CU), and average particle size (d_{50}) (see Table 2.14). One of these three approaches should be used. The approach should be chosen on the basis of the criticality of the situation being considered, since the approaches are restrictive to different degrees.

TABLE 2.14 RELATIONSHIPS USED TO OBTAIN FABRIC OPENING SIZE TO PREDICT EXCESSIVE LOSS OF FINES DURING FILTRATION*

Relative density	$1 + CU - 3$	$CU - 3$
Loose ($D_R \leq 50\%$)	$d_{0.5} < (CU)(d_{50})$	$d_{0.5} < (9d_{50})/CU$
Intermediate ($50\% < D_R > 80\%$)	$d_{0.5} < 1.5(CU)(d_{50})$	$d_{0.5} < (13.5d_{50})/CU$
Dense ($D_R > 80\%$)	$d_{0.5} < 2(CU)(d_{50})$	$d_{0.5} < (18d_{50})/CU$

Source: After Giroud [42]

* d_{50} , Soil particle size corresponding to 50% finer; CU , coefficient of uniformity ($=d_{60}/d_{10}$); d_{10} , soil particle size corresponding to 10% finer; d_{60} , soil particle size corresponding to 60% finer; $d_{0.5}$, apparent opening size of geotextile (if data are not given by the manufacturer, this value is approximately the AOS sieve value in millimeters).

2.4.3.3 Long-Term Compatibility

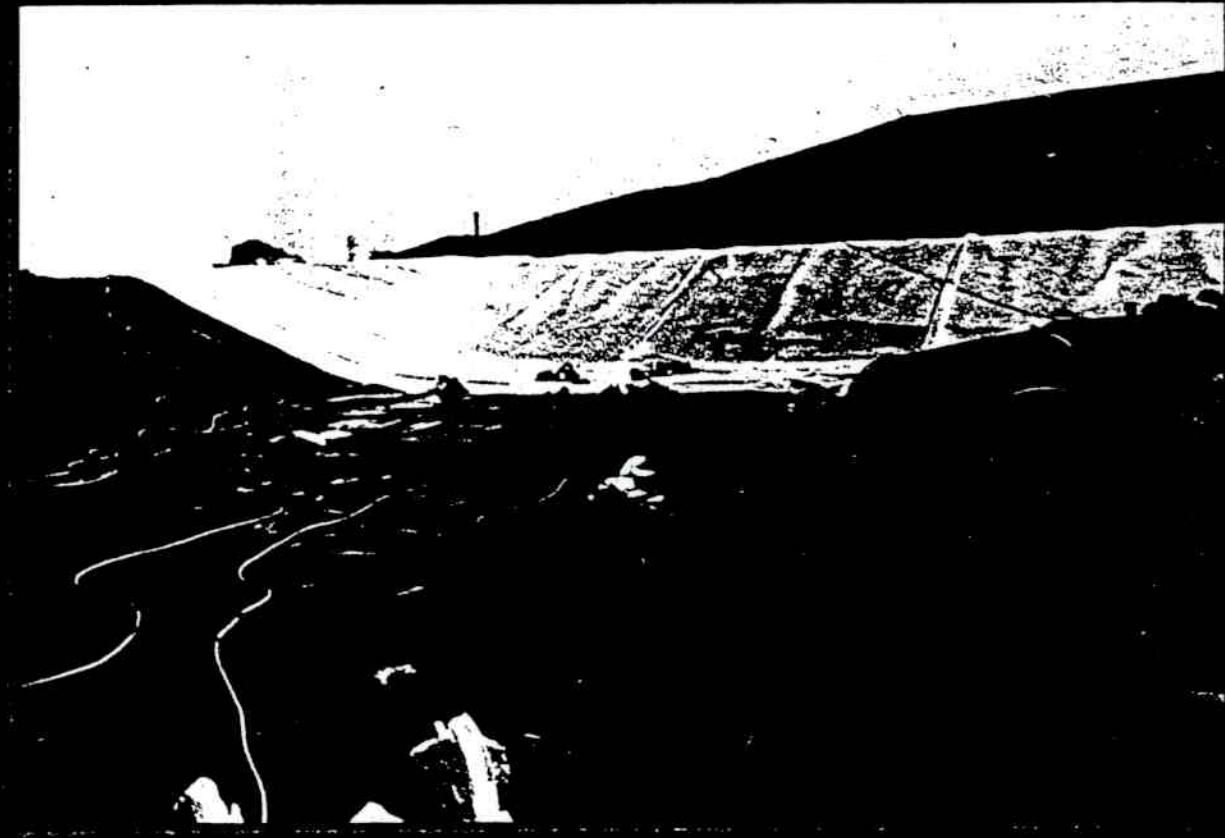
Perhaps the most asked question in the use of geotextiles in hydraulic related systems is, "Will it clog?" Obviously, some soil particles will embed themselves within the fabric structure, but the question really asks if the fabric will completely clog, such that the flow of liquid through it will be completely shut off. The question can be directly answered by taking a soil sample and the candidate geotextile(s) and testing them in the laboratory in either gradient ratio tests [27] to see that the $GR \leq 3.0$, or long-term flow tests [26] to see that the terminal slope of the flow rate versus time curve is essentially zero (recall Sections 2.2.5.5 and 2.2.5.4).

Another approach to a suitable answer to the clogging question posed is simply to avoid situations that have been known to lead to severe clogging problems. From experience it has been shown that three conditions are necessary to have a high likelihood of complete soil clogging of geotextile filters:

1. cohesionless sands and silts,
2. gap-graded particle size distribution, and
3. high hydraulic gradients.

SECOND EDITION

DESIGNING WITH GEOSYNTHETICS



-ROBERT M. KOERNER-



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page <u>1</u> of <u>2</u>					
Proj. No.	Client	Location	Subject		
16139	PROTELCO	Ponceles Puerto Rico	DownLaser Discharge Pipe		
Preparer's Initials JEB	Date 11/13/95	Reviewer's Initials JKO	Date 11/13/95	Approver's Initials	Date

Size discharge pipe for down slope edge of cover cap.

Based on HELP Model for 1 acre area over units 9, 10, 11, 12, and 16 with $L = 383\text{ ft}$ at an avg slope of 5% the Peak Daily Drainage from layer 3 is $104.8 \text{ ft}^3/\text{day/acre}$

$$Q = \left(104.8 \frac{\text{ft}^3}{\text{day}}\right) \left(\frac{1 \text{ day}}{24 \text{ hr}}\right) \left(\frac{1 \text{ hr}}{60 \text{ min}}\right) \left(\frac{1 \text{ min}}{60 \text{ sec}}\right)$$

$$Q = 0.0012 \text{ cfs/acre} \checkmark$$

Discharge pipe in down slope edge of draining trench is 4" HDPE

Assume pipe to be flowing full = $R = D/4$

$$\text{Slope} = 2\% \text{ min}$$

$$n = 0.010$$

$$Q = \left(\frac{1.49}{n}\right)(A)(R)^{2/3}(S)^{0.5}$$

$$Q = \left(\frac{1.49}{0.010}\right) \left(\pi \left(\frac{4}{2}\right)^2\right) \left(\frac{4}{4}\right)^{2/3} (0.02)^{0.5}$$

$$\underline{Q_{4''} = 0.35 \text{ cfs}} \checkmark$$

Based on acreage at the closure caps, Q for each cap is as follows

Unit 1 - $A = 8456 \text{ ft}^2 = 0.19 \text{ Ac} \checkmark$

$$Q_1 = (0.19)(0.0012 \text{ cfs/acre}) \Rightarrow Q_1 = 0.0002 \text{ cfs} \ll 0.35 \text{ cfs}, \text{OK}$$

Unit 2 & 3 - $A = 12,670 \text{ ft}^2 = 0.29 \text{ Ac} \checkmark$

$$Q_2 = (0.29)(0.0012 \text{ cfs/acre}) \Rightarrow Q_2 = 0.0003 \text{ cfs} \ll 0.35 \text{ cfs}, \text{OK}$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89Page 2 of 2

Proj. No. 16139	Client PROTECO	Location Penuelcs Puerto Rico	Subject Drainage Layer Ditching Pipe
Preparer's Initials JEB	Date 11/13/95	Reviewer's Initials JKO	Date 11/13/95

$$\text{Unit 5} - A = 16,215 \text{ ft}^2 = 0.37 \text{ Ac} \checkmark$$

$$Q_5 = (0.37 \text{ Ac})(0.0012 \text{ cfs/ft}^2) \Rightarrow Q_5 = 0.0004 \text{ cfs} \checkmark < 0.35 \text{ cfs} \therefore \text{OK}$$

$$\text{Unit 7, 9, 12, 16} - A = 114,160 \text{ ft}^2 = 2.62 \text{ Ac} \checkmark$$

$$Q_9 = (2.62 \text{ Ac})(0.0012 \text{ cfs/ft}^2) \Rightarrow Q_9 = 0.003 \text{ cfs} \checkmark < 0.35 \text{ cfs} \therefore \text{OK}$$

$$\text{Unit 13} - A = 13,032 \text{ ft}^2 = 0.30 \text{ Ac} \checkmark$$

$$Q_{13} = (0.30 \text{ Ac})(0.0012 \text{ cfs/ft}^2) \Rightarrow Q_{13} = 0.0004 \text{ cfs} \checkmark < 0.35 \text{ cfs} \therefore \text{OK}$$

$$\text{Unit 17} - A = 10,496 \text{ ft}^2 = 0.24 \text{ Ac} \checkmark$$

$$Q_{17} = (0.24 \text{ Ac})(0.0012 \text{ cfs/ft}^2) \Rightarrow Q_{17} = 0.0003 \text{ cfs} \checkmark < 0.35 \text{ cfs} \therefore \text{OK}$$

Thus, 4" # drain pipe along to downslope edge of the closer cap (as shown on the construction drawings will be sufficient to carry the Peak Daily Flow from each unit.

APPENDIX B

STORMWATER GENERATION RATE CALCULATIONS



OHM Corporation

COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 1 of 10

Proj. No.	Client	Location	Subject
1613-1	DOFECO	Ponceles, Puerto Rico	Drainage Calculations
Preparer's Initials	Date	Reviewer's Initials	Date
JEB	9-25-94	MCP	9-29-94

Drainage Calculations

Drainage Calculations are based on the rational method where $Q = CIA$

where Q = flow rate in CFS

C = runoff coefficient

I = rainfall intensity in inches/hour

A = drainage area in acres

(C) The runoff coefficients are based on the proposed final cap/cover for each waste unit and surrounding area.

The "C" values are based on the average of "C" values obtained from the "Erosion and Sediment Control Handbook" in the "Hesilite Stormwater Management Manual". See references.

The "C" values are based on the slope, landuse, and type of soil for a particular drainage area. The "C" values used for these drainage calculations are as follows:

- 1) Steep slope ($> 7\%$), Woodland, Heavy vegetative cover, with heavy soils $\Rightarrow \underline{C = 0.31}$
- 2) Steep slope ($> 7\%$), Pasture, grass, lawn, with heavy soil $\Rightarrow \underline{C = 0.43}$
- 3) Rolling slope ($\leq 7\%$), Pasture, grass, lawn, with heavy soil $\Rightarrow \underline{C = 0.27}$

For most drainage areas, a weighted "C" value will be calculated to determine the effective runoff coefficient. Weighted "C" values are shown for each separate drainage area.



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 2 of 10

Proj. No. <u>10139</u>	Client <u>PROTELCO</u>	Location <u>Ponceles, Puerto Rico</u>	Subject <u>Drainage Calculations</u>
Preparer's Initials <u>JEB</u>	Date <u>9-25-94</u>	Reviewer's Initials <u>MLP</u>	Date <u>9-29-94</u>

The Intensity value "I" is based on a 100 year, 1 hour duration storm event for Ponceles, Puerto Rico. The I value was obtained from Technical Paper No. 42 (See reference). I₁₀₀ for 1 hour duration, based on the enclosed chart is:

$$5.25 \text{ inches for a 1 hour duration, thus,}$$
$$\underline{I = 5.25 \text{ inches per hour}}$$

Note:

To date, rainfall intensity/duration curves^v do not exist for Puerto Rico. Various agencies were contacted (U.S.G.S., SCS, NOAA, N.C.D.C.) in regards to these curves and they all stated that they use Technical Paper No. 42 for rainfall data, and do not know of any rainfall duration curves that exist.

and/or nomographs

The drainage areas were calculated using a polar planimeter on either a 1"-40', 1"-100' or 1"-1,667' scale. The drainage area are broken down into "on-site" and "off-site" areas. On-site areas were calculated from the 1"-40' and 1"-100' site plans and the off-site areas were calculated on the 1"-1,667' U.S.G.S. topographic Survey.

A site plan showing the "on-site" and off-site drainage areas are attached.



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 3 of 10

Proj. No. 16139	Client PROECO	Location Penuelos, Puerto Rico	Subject Draining Calculations
Preparer's Initials JEB	Date 9-25-94	Reviewer's Initials MLP	Date 9-29-94

Reach "A"

$$\begin{aligned} \text{On-Site Area} &= 64.75 \text{ in}^2 \text{ (on a } 1'' = 40' \text{ scale)} \\ &= 103,600 \text{ ft}^2 \\ &= 2.38 \text{ Acres} \end{aligned}$$

$$\begin{aligned} \text{Off-Site Area} &= 230 \text{ in}^2 \text{ (on a } 1'' = 40' \text{ scale)} \\ &= 3680 \text{ ft}^2 \\ &= 0.09 \text{ acres} \end{aligned}$$

$$\underline{\text{Total Area}} = 2.47 \text{ acres}$$

$$\underline{C = 0.43} \text{ (See C value no. 2 on sheet 1)}$$

$$\begin{aligned} Q_A &= (0.43) \times (5.25 \text{ in/hr}) (2.47 \text{ acres}) \\ \underline{Q_A} &= 5.6 \text{ cfs} \end{aligned}$$

Reach "B"

$$\begin{aligned} \text{On-site area} &= 66.25 \text{ in}^2 \text{ (on a } 1'' = 40' \text{ scale)} \\ &= 106,000 \text{ ft}^2 \\ &= 2.43 \text{ Acres} \end{aligned}$$

$$\begin{aligned} \text{Off-site area} &= 013 \text{ in}^2 \text{ (on a } 1'' = 166' \text{ scale)} \\ &= 361,256 \text{ ft}^2 \\ &= 8.29 \text{ Acres} \end{aligned}$$

$$\underline{\text{Total Area}} = 10.72 \text{ Acres}$$

Weighted "C" = 22% is C value #2 and 78% is C value #1 (see sheet 1)

$$C = (0.22)(0.43) + (0.78)(0.31)$$

$$\underline{C = 0.34}$$

$$\begin{aligned} Q_B &= (0.34)(5.25 \text{ in/hr}) (10.72 \text{ acres}) \\ \underline{Q_B} &= 19.1 \text{ cfs} \end{aligned}$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08-89

Page 4 of 10

Proj. No.	Client	Location	Subject
16139	PROTECO	Poncelet, Puerto Rico	Drainage Calculations
Preparer's Initials	Date	Reviewer's Initials	Approver's Initials

Reach "C"

$$\text{On-Site Area} = 40.35 \text{ in}^2 \text{ (con = 1" = 40' scale)} \\ = 64,560 \text{ ft}^2$$

$$= 1.48 \text{ acres}$$

$$\text{Off-Site Area} = 0.16 \text{ in}^2 \text{ (con = 1" = 1,667' scale)} \\ = 444,622 \text{ ft}^2$$

$$= 10.21 \text{ acres}$$

$$\underline{\text{Total Area}} = \underline{11.69 \text{ acres}}$$

Weighted C = 13% is C value #2 and 87% is C value #1 (see sheet 1)

$$C = (0.13)(0.43) + (0.87)(0.31)$$

$$\underline{C = 0.33}$$

$$Q_C = (0.33)(5.25 \text{ in/hr})(11.69 \text{ acres}) \\ \underline{Q_C = 20.3 \text{ cfs}}$$

Reach "D"

$$\text{On-Site Area} = 43.49 \text{ in}^2 \text{ (con = 1" = 40' scale)} - \text{all of drainage area on-site} \\ = 69,584 \text{ ft}^2$$

$$\underline{\text{Total Area}} = \underline{1.60 \text{ acres}}$$

C = 0.43 - (see C value #2 on sheet 1)

$$Q_D = (0.43)(5.25 \text{ in/hr})(1.60 \text{ acres})$$

$$\underline{Q_D = 3.6 \text{ cfs}}$$

Reach "E"

$$\text{On-Site Area} = 11.48 \text{ in}^2 \text{ (con = 1" = 40' scale)} - \text{all of drainage area on-site} \\ = 18,368 \text{ ft}^2$$

$$\underline{\text{Total Area}} = \underline{0.42 \text{ Acres}}$$

C = 0.43 - (See C value #2 on sheet 1)

$$Q_E = (0.43)(5.25 \text{ in/hr})(0.42 \text{ acres})$$

$$\underline{Q_E = 1.0 \text{ cfs}}$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 5 of 10

Proj. No.	Client	Location	Subject		
16139	PROTECO	Ponce, Puerto Rico	Drainage Calculations		
Preparer's Initials	Date	Reviewer's Initials	Date	Approver's Initials	Date
JEB	9-25-94	MLP	9-29-94		

Rock "F"

$$\begin{aligned} \text{On-Site Area} &= 13.12 \text{ m}^2 (\text{on } 1'' = 40 \text{ scale}) \\ &= 20,992 \text{ ft}^2 \\ &= 0.48 \text{ acres} \end{aligned}$$

$$\begin{aligned} \text{Off-Site Area} &= 0.16 \text{ m}^2 (\text{on } 1'' = 1,667 \text{ scale}) \\ &= 444,622 \text{ ft}^2 \\ &= 10.21 \text{ acres} \end{aligned}$$

$$\underline{\text{Total Area}} = 10.69 \text{ acres}$$

$$\begin{aligned} \text{Weighted C} &= 57\% \text{ is C value #2 and } 95\% \text{ is C value #1 (see sheet 1)} \\ C &= (0.05)(0.43) + (0.95)(0.31) \\ C &= 0.32 \end{aligned}$$

$$\begin{aligned} Q_f &= (0.32)(5.25 \text{ in/hr})(10.69 \text{ acres}) \\ Q_f &= 18.0 \text{ cfs} \end{aligned}$$

Rock "G"

$$\begin{aligned} \text{On-Site Area} &= 9.82 \text{ m}^2 (\text{on } 1'' = 40 \text{ scale}) \\ &= 15,712 \text{ ft}^2 \\ &= 0.36 \text{ acres} \end{aligned}$$

$$\begin{aligned} \text{Off-Site Area} &= 0.36 \text{ m}^2 (\text{on } 1'' = 1,667 \text{ scale}) \\ &= 1,000,400 \text{ ft}^2 \\ &= 22.97 \text{ acres} \end{aligned}$$

$$\underline{\text{Total Area}} = 23.33 \text{ acres}$$

$$\begin{aligned} \text{Weighted C} &= 27\% \text{ is C value #2 and } 98\% \text{ is C value #1 (see sheet 1)} \\ C &= (0.02)(0.43) + (0.98)(0.31) \\ C &= 0.31 \end{aligned}$$

$$\begin{aligned} Q_G &= (0.31)(5.25 \text{ in/hr})(23.33 \text{ acres}) \\ Q_G &= 38.0 \text{ cfs} \end{aligned}$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 6 of 10

Proj. No.	Client	Location	Subject
16139	PROTECO	Ponceles, Puerto Rico	Draining Calculations
Preparer's Initials	Date	Reviewer's Initials	Date
JEB	9-25-94	MLP	9-29-94

Reach "H"

$$\begin{aligned} \text{On-Site Area} &= 1713 \text{ in}^2 (\text{con} = 1'' = 410 \text{ square}) \\ &= 27,408 \text{ ft}^2 \\ &= 0.63 \text{ Acres} \end{aligned}$$

$$\begin{aligned} \text{Off-Site Area} &= 0.21 \text{ in}^2 (\text{con} = 1'' = 1667 \text{ square}) \\ &= 383,567 \text{ ft}^2 \\ &= 13.40 \text{ acres} \end{aligned}$$

$$\begin{aligned} \text{Total Area} &= 14.03 \text{ acres} \end{aligned}$$

$$\begin{aligned} \text{Weight C} &= 57\% \text{ is C value #2 and } 95\% \text{ is C value #1 (see sheet 1)} \\ C &= (0.05)(0.43) + (0.95)(0.31) \\ \underline{\underline{C = 0.32}} \end{aligned}$$

$$\begin{aligned} Q_4 &= (0.32)(5.25 \text{ in/hr})(14.03 \text{ acres}) \\ \underline{\underline{Q_H = 23.6 \text{ cfs}}} \end{aligned}$$

Reach "I"

$$\begin{aligned} \text{On-Site Area} &= 0.54 \text{ in}^2 (\text{con} = 1'' = 100 \text{ square}) - \text{all area is on-site} \\ &= 5,400 \text{ ft}^2 \end{aligned}$$

$$\begin{aligned} \text{Total Area} &= 0.12 \text{ acres} \end{aligned}$$

$$\underline{\underline{C = 0.43 \text{ (See C value #2 on sheet 1)}}}$$

$$\begin{aligned} Q_I &= (0.43)(5.25 \text{ in/hr})(0.12 \text{ acres}) \\ \underline{\underline{Q_I = 0.3 \text{ cfs}}} \end{aligned}$$

Reach "J"

Reach "J" collects drainage areas/reaches "F," "G," "H," and "I"

$$\text{Thus, } Q_J = (18.0 + 38.0 + 23.6 + 0.3) \text{ cfs}$$

$$\underline{\underline{Q_J = 79.9 \text{ cfs}}}$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 7 of 10

Proj. No. <u>16139</u>	Client <u>PROTECO</u>	Location <u>Ponceles, Puerto Rico</u>	Subject <u>Drawing Calculations</u>
Preparer's Initials <u>JEB</u>	Date <u>9-25-94</u>	Reviewer's Initials <u>MLP</u>	Date <u>9-29-94</u>

Existing Drainage Ditch "A"

$$\text{Off-site Drainage Area} = 17.08 \cdot 3 (\text{in} \cdot 1^{\circ} = 100 \text{ sec}) - \text{all area is off-site} \\ = 170,800 \text{ ft}^2$$

$$\text{Total Area} = 3.92 \text{ acres}$$

$$C = 0.31 \quad (\text{See } C \text{ value # 1 on sheet 1})$$

$$Q_{EA} = (0.31)(5.25 \text{ in/hour})(3.92 \text{ acres})$$

$$Q_{EA} = 6.4 \text{ cfs}$$

Existing Drainage Ditch "B"

$$\text{On-Site Area} = 0.7558 \cdot 2 (\text{in} \cdot 1^{\circ} = 40 \text{ sec}) \\ = 120,928 \text{ ft}^2$$

$$= 2.78 \text{ Acres}$$

$$\text{Off-Site Area} = 0.32 \cdot 3 (\text{in} \cdot 1^{\circ} = 1,667 \text{ sec}) \\ = 889,244 \text{ ft}^2$$

$$= 20.41 \text{ acres}$$

$$\text{Total Area} = 23.19 \text{ Acres}$$

Weighted C = 12% is C value # 2 and 88% is C value # 1 (see sheet 1)

$$C = (0.12)(0.43) + (0.88)(0.31)$$

$$C = 0.32$$

$$Q_{EB} = (0.32)(5.25 \text{ in/hr})(23.19 \text{ Acres})$$

$$Q_{EB} = 39.0 \text{ cfs}$$

Reach "K"

Reach "KL" receives/collects existing drainage ditch "B"

$$\text{Thus } Q_{KL} = Q_{EB} = 39.0 \text{ cfs}$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 8 of 10

Proj. No.	Client	Location	Subject
16129	PROTECO	Ponceles, Puerto Rico	Drainage Calculations
Preparer's Initials	Date	Reviewer's Initials	Approver's Initials

Overland Flow #2 (OF2)

$$\text{On-site Area} = 96.52 \text{ in}^2 \quad (\text{cm} = 1^{\circ} = 100 \text{ scale})$$

$$= 965,200 \text{ ft}^2$$

$$= 22.16 \text{ Acres}$$

$$\text{Off-site Area} = 0.98 \text{ in}^2 \quad (\text{cm} = 1^{\circ} = 1,667 \text{ scale})$$

$$= 2,723,311 \text{ ft}^2$$

$$= 62.52 \text{ Acres}$$

$$\text{Total Area} = 84.68 \text{ Acres}$$

Weighted C = 26% is C value #2 and 74% is C value #1 (see sheet)
 $C = (0.26)(0.43) + (0.74)(0.31)$
 $\underline{C = 0.34}$

$$Q_{OF2} = (0.34)(5.25 \text{ in/hr})(84.68 \text{ Acres})$$

$$\underline{Q_{OF2} = 151.2 \text{ cfs}}$$

Retention Basin

$$\text{On-Site Area} = 93.93 \text{ in}^2 \quad (\text{cm} = 1^{\circ} = 40 \text{ scale})$$

$$= 939,300 \text{ ft}^2$$

$$= 3.45 \text{ Acres}$$

$$\text{Off-site Area} = 0.37 \text{ in}^2 \quad (\text{cm} = 1^{\circ} = 1,667 \text{ scale})$$

$$= 1,028,119 \text{ ft}^2$$

$$= 23.60 \text{ Acres}$$

$$\text{Total Area} = 27.05$$

Weighted C = 14% is C value #2 and 86% is C value #1 (see sheet)
 $C = (0.14)(0.43) + (0.86)(0.31)$
 $\underline{C = 0.33}$

$$Q_{RB} = (0.33)(5.25 \text{ in/hr})(27.05 \text{ Acres})$$

$$\underline{Q_{RB} = 46.9 \text{ cfs}}$$

Total Flow into the retention basin (Q_{RBT}) is the summation of

$$Q_{RBT} = \sum Q_{OF} + Q_f + Q_s + Q_u + Q_I + Q_{RB}$$

$$Q_{RBT} = (46.9 + 18.0 + 38.0 + 23.6 + 0.3 + 39.0) \text{ cfs}$$

$$\underline{Q_{RBT} = 165.8 \text{ cfs}}$$



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 9 of 10

Proj. No.	Client		Subject	
16139	PROTECO		Penuelas, Puerto Rico	
Preparer's Initials	Date	Reviewer's Initials	Approver's Initials	Date
JEB	9-29-94	MLP		9-29-94

Drainage Overland Flow #1 (OF1)

$$\begin{aligned}\text{On-Site Area} &= 60,32 \text{ in}^2 \quad (\text{in} = 1'' = 100 \text{ sec/u}) \\ &= 603,200 \text{ ft}^2 \\ &= 13.85 \text{ Acres}\end{aligned}$$

$$\begin{aligned}\text{Of-Site Area} &= 0.43 \text{ in}^2 \quad (\text{in} = 1'' = 1,407.5 \text{ sec/u}) \\ &= 1,194,922 \\ &= 27.43 \text{ Acres}\end{aligned}$$

$$\text{Total Area} = 41.28 \text{ Acres}$$

$$\begin{aligned}\text{Weighted } C &= 34\% \text{ is } C \text{ value } \#3 \text{ and } 66\% \text{ is } C \text{ value } \#1 \text{ (see sheet 1)} \\ C &= (0.34)(0.27) + (0.66)(0.31) \\ C &= 0.30\end{aligned}$$

$$\begin{aligned}Q_{OF1} &= (0.30)(5.25 \text{ in}) / (41.28 \text{ Acre}) \\ Q_{OF1} &= 65.0 \text{ cfs}\end{aligned}$$

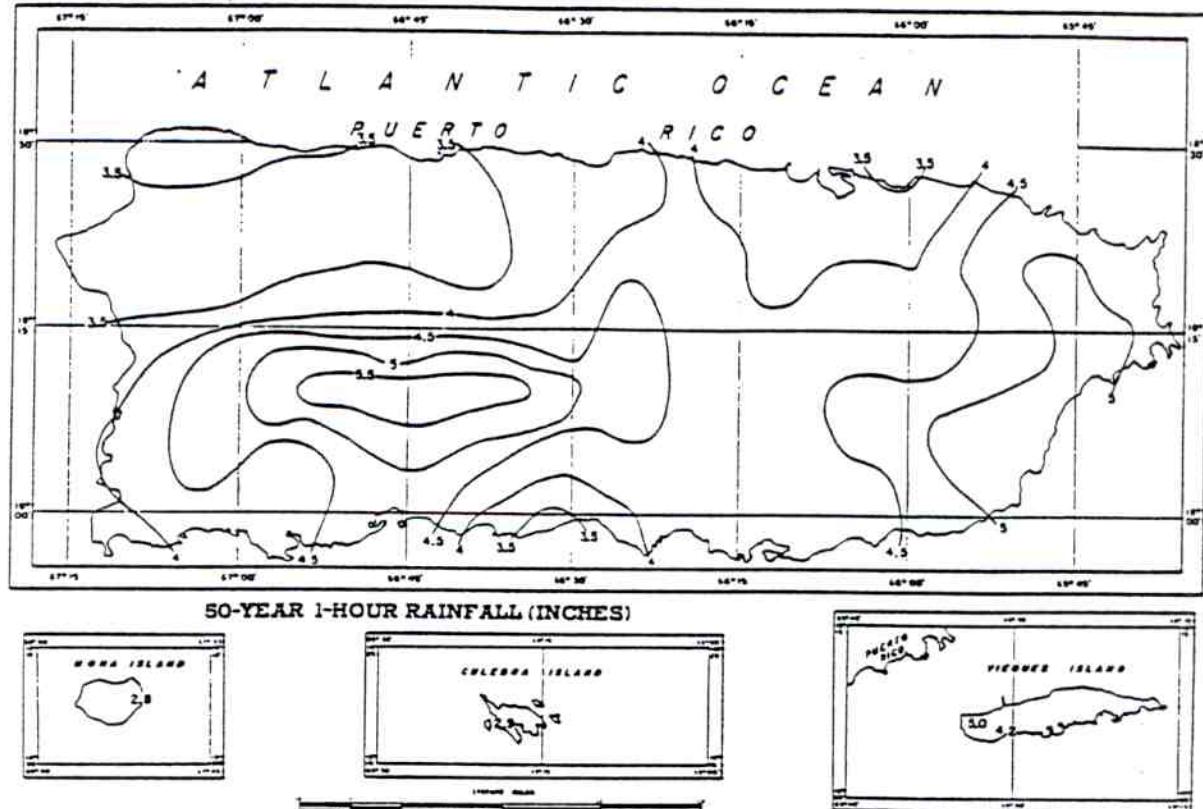


FIGURE 4-19.—50-yr. 1-hr. rainfall for Puerto Rico (in.)

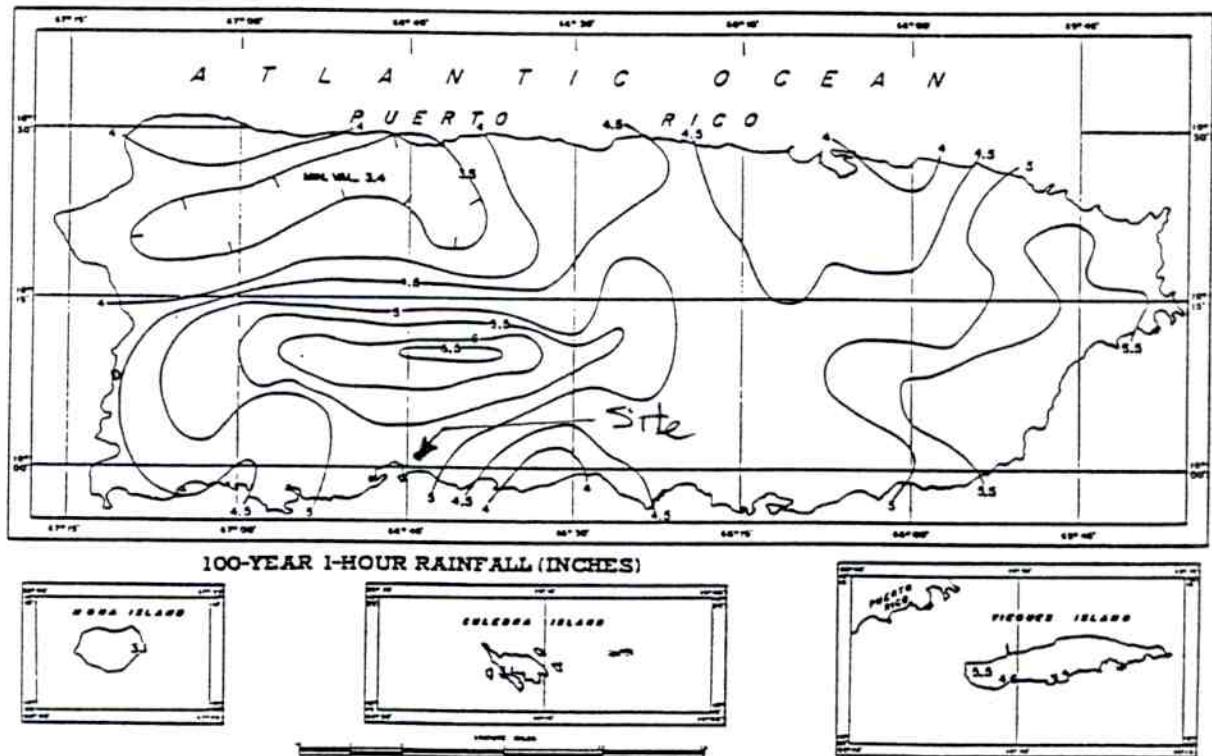


FIGURE 4-20.—100-yr. 1-hr. rainfall for Puerto Rico (in.).

APPENDIX C

**STORMWATER DRAINAGE CHANNEL
AND CULVERT CALCULATIONS**



COMPUTATION SHEET

OHM Corporation

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 1 of 29

Proj. No. <u>16139</u>	Client <u>PROTECO</u>	Location <u>Ponceletas, PR</u>	Subject <u>Drainage Swales</u>
Preparer's Initials <u>JAL</u>	Date <u>9/1/94</u>	Reviewer's Initials <u>MCP</u>	Date <u>9/21/94</u>

Reach "A" Drainage Swale

Check Min. slope section for capacity.

$$Q = 5.6 \text{ cfs}$$

Determine flow depth

$$Q = \frac{1.49}{n} (R_H)^{2/3} (S)^{1/2} A$$

$$\text{For } 8:1 \text{ Slope} \quad R_H = \frac{A}{P} = \frac{(4(d)) + (8d(d))}{4 + 2\sqrt{d^2 + 8d^2}}$$

$$19.1 = \frac{1.49}{0.031} \left(\frac{4d + 8d(d)}{4 + 2(\sqrt{d^2 + 8d^2})} \right)^{2/3} (0.044)^{1/2} (4d + 8d(d))$$

From Reach "A" spreadsheet, flow depth = 0.27 ft

channel depth = 2.5' \therefore Channel depth sufficient
Determine velocity for rip-rap sizing at max. slope

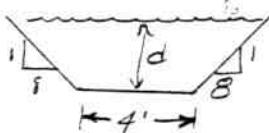
$$V = \frac{1.49}{n} (R_H)^{2/3} (S)^{1/2} \quad R_H = \frac{(4d) + (2d(d))}{4 + 2(\sqrt{d^2 + 2d^2})}$$

From 8% Slope spreadsheet, velocity $\approx 4.93 \text{ fps}$

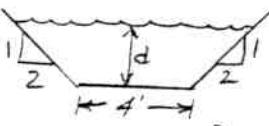
\therefore Use NSA No. R-3 Rock $n = 0.031$

$$\text{Max. } D_{50} = 6'' \quad \text{Min. } D_{50} = 3''$$

Ref. Erosion and Sediment Control Handbook
Goldman, Jackson & Borszczynsky



$$\text{Min. } S = \frac{2}{45} = 4.4\%$$



$$\text{Max. } S = \frac{2}{8} = 8\%$$

PROTECO LANDFILL
REACH "A" DRAINAGE CALCULATIONS
FOR SLOPE = 4.4%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.93	0.031	0.044	0.1	0.48	5.61	1.94
3.24	0.031	0.044	0.2	1.12	7.22	2.89
5.29	0.031	0.044	0.26	1.58	8.19	3.35
5.69	0.031	0.044	0.27	1.66	8.35	3.42
6.10	0.031	0.044	0.28	1.75	8.51	3.49
6.52	0.031	0.044	0.29	1.83	8.68	3.56
6.96	0.031	0.044	0.3	1.92	8.84	3.63
12.24	0.031	0.044	0.4	2.88	10.45	4.25
15.52	0.031	0.044	0.45	3.42	11.26	4.54
19.25	0.031	0.044	0.5	4.00	12.06	4.81
28.14	0.031	0.044	0.6	5.28	13.67	5.33
39.06	0.031	0.044	0.7	6.72	15.29	5.81
52.18	0.031	0.044	0.8	8.32	16.90	6.27
67.63	0.031	0.044	0.9	10.08	18.51	6.71
85.56	0.031	0.044	1	12.00	20.12	7.13
106.12	0.031	0.044	1.1	14.08	21.74	7.54
129.43	0.031	0.044	1.2	16.32	23.35	7.93
155.64	0.031	0.044	1.3	18.72	24.96	8.31
184.87	0.031	0.044	1.4	21.28	26.57	8.69
217.26	0.031	0.044	1.5	24.00	28.19	9.05
252.92	0.031	0.044	1.6	26.88	29.80	9.41

PROTECO LANDFILL
REACH "A" DRAINAGE CALCULATIONS
FOR SLOPE = 8%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
1.17	0.031	0.08	0.1	0.42	4.45	2.80
3.79	0.031	0.08	0.2	0.88	4.89	4.31
5.17	0.031	0.08	0.24	1.08	5.07	4.81
5.54	0.031	0.08	0.25	1.13	5.12	4.93
5.93	0.031	0.08	0.26	1.18	5.16	5.04
7.58	0.031	0.08	0.3	1.38	5.34	5.49
12.46	0.031	0.08	0.4	1.92	5.79	6.49
18.42	0.031	0.08	0.5	2.50	6.24	7.37
21.81	0.031	0.08	0.55	2.81	6.46	7.77
25.46	0.031	0.08	0.6	3.12	6.68	8.16
33.59	0.031	0.08	0.7	3.78	7.13	8.89
42.83	0.031	0.08	0.8	4.48	7.58	9.56
53.20	0.031	0.08	0.9	5.22	8.02	10.19



OHM Corporation

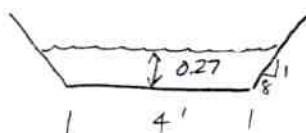
COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page 2 of 29

Proj. No. 16139	Client PROTECO	Location Ponceletas, PR	Subject Drainage Swales
Preparer's Initials	Date	Reviewer's Initials MLP	Date 9/21/94

Check Reach "A" spreadsheet for $S = 4.4\%$, $d = 0.27$



$$A = 4(0.27) + 2(\frac{1}{2}(8(0.27)))(.27)$$

$$A = 1.08 + 0.58 = 1.66$$

$$P = 4 + 2\sqrt{0.27^2 + (8(0.27))^2}$$

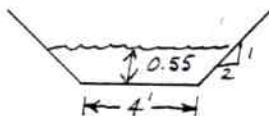
$$P = 8.35$$

$$Q = 1.66 \left(\frac{1.49}{0.031}\right) \left(\frac{1.66}{8.35}\right)^{0.67} (0.044)^{\frac{1}{2}}$$

$$Q = 1.66 (48.06) (0.34) (0.21)$$

$$Q = 5.67 \text{ ft } \text{OK}$$

Check Reach "A" spreadsheet for $S = 8\%$, $d = 0.25$



$$A = 4(0.25) + 2(\frac{1}{2}(2(0.25))(0.25))$$

$$A = 1.13 \text{ ft}^2$$

$$P = 4 + 2\sqrt{0.25^2 + (2(0.25))^2}$$

$$P = 4 + 1.12 = 5.12$$

$$Q = 1.13 \left(\frac{1.49}{0.031}\right) \left(\frac{1.13}{5.12}\right)^{0.67} (0.08)^{\frac{1}{2}}$$

$$Q = 1.13 (48.06) (0.34)$$

$$Q = 5.58 \text{ ft } \text{OK}$$



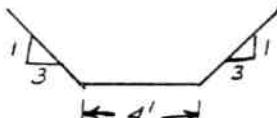
COMPUTATION SHEET

OHM Corporation

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page 3 of 29

Proj. No. 10139	Client PROTECO	Location Penuelas, PR	Subject Drainage Swales
Preparer's Initials JAL	Date 9/2/94	Reviewer's Initials MLP	Date 9/21/94

Reach "B" Drainage Swale

Check Min. Slope section for capacity

$$\text{Min. } S = 3.3\%$$

$$Q = 19.1 \text{ cfs}$$

Determine flow depth

$$R_H = \frac{A}{P} = \frac{(4d) + (3d(d))}{4 + 2(d^2 + 3d^2)^{1/2}}$$

$$\text{assume } n = 0.035$$

$$19.1 = \frac{1.49}{0.035} \left(\frac{4d + 3d(d)}{4 + 2(d^2 + 3d^2)^{1/2}} \right) (0.033)^{1/2} (12d^3)$$

From 3.3% Slope spreadsheet, flow depth = 0.77 ft

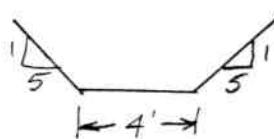
Channel depth = 3' \therefore Channel depth sufficient

Determine velocity for rip-rap sizing at max. slope

$$\text{Max. } S = 8\%$$

$$R_H = \frac{A}{P} = \frac{4d + 5d(d)}{4 + 2(\sqrt{d^2 + 5d^2})}$$

$$V = \frac{1.49}{0.035} \left(\frac{4d + 5d(d)}{4 + 2(\sqrt{d^2 + 5d^2})} \right)^{0.67} (0.08)^{1/2}$$



$$\text{Max. } S = 8\%$$

From Reach "B" 8% Slope Spreadsheet $V \approx 6.0 \text{ fps}$ Check for $n = 0.031$ for possible use of R-3 rip rapFrom spreadsheet w/ $n = 0.031$ Velocity > 6.5 fps \therefore Use R-4 rip rap

PROTECO LANDFILL
REACH "B" DRAINAGE CALCULATIONS

FOR SLOPE = 3.3%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.68	0.035	0.033	0.1	0.43	4.63	1.57
2.21	0.035	0.033	0.2	0.92	5.26	2.40
4.48	0.035	0.033	0.3	1.47	5.90	3.05
7.47	0.035	0.033	0.4	2.08	6.53	3.59
11.20	0.035	0.033	0.5	2.75	7.16	4.07
15.68	0.035	0.033	0.6	3.48	7.79	4.51
18.21	0.035	0.033	0.65	3.87	8.11	4.71
18.74	0.035	0.033	0.66	3.95	8.17	4.75
19.28	0.035	0.033	0.67	4.03	8.24	4.79
19.82	0.035	0.033	0.68	4.11	8.30	4.83
20.94	0.035	0.033	0.7	4.27	8.43	4.90
23.27	0.035	0.033	0.74	4.60	8.68	5.06
27.01	0.035	0.033	0.8	5.12	9.06	5.28
33.93	0.035	0.033	0.9	6.03	9.69	5.63
41.72	0.035	0.033	1	7.00	10.32	5.96
50.43	0.035	0.033	1.1	8.03	10.96	6.28

PROTECO LANDFILL
REACH "B" DRAINAGE CALCULATIONS

FOR SLOPE = 8%

Flow (cfs)	n	Slope (%)	Flow Dept (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
1.08	0.035	0.08	0.1	0.45	5.02	2.39
3.61	0.035	0.08	0.2	1.00	6.04	3.61
7.50	0.035	0.08	0.3	1.65	7.06	4.55
12.81	0.035	0.08	0.4	2.40	8.08	5.34
17.42	0.035	0.08	0.47	2.98	8.79	5.84
18.14	0.035	0.08	0.48	3.07	8.90	5.91
18.88	0.035	0.08	0.49	3.16	9.00	5.97
19.63	0.035	0.08	0.5	3.25	9.10	6.04
25.36	0.035	0.08	0.57	3.90	9.81	6.49
28.06	0.035	0.08	0.6	4.20	10.12	6.68
38.19	0.035	0.08	0.7	5.25	11.14	7.27
50.13	0.035	0.08	0.8	6.40	12.16	7.83

PROTECO LANDFILL
REACH "B" DRAINAGE CALCULATIONS

FOR SLOPE = 8%, n=0.031

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
1.22	0.031	0.08	0.1	0.45	5.02	2.70
4.07	0.031	0.08	0.2	1.00	6.04	4.07
8.47	0.031	0.08	0.3	1.65	7.06	5.13
14.47	0.031	0.08	0.4	2.40	8.08	6.03
18.10	0.031	0.08	0.45	2.81	8.59	6.43
18.88	0.031	0.08	0.46	2.90	8.69	6.51
19.67	0.031	0.08	0.47	2.98	8.79	6.59
22.17	0.031	0.08	0.5	3.25	9.10	6.82
31.68	0.031	0.08	0.6	4.20	10.12	7.54
43.12	0.031	0.08	0.7	5.25	11.14	8.21
56.60	0.031	0.08	0.8	6.40	12.16	8.84



COMPUTATION SHEET

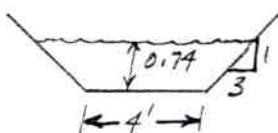
OHM Corporation

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page 4 of 29

Proj. No. 16139	Client PROTECO	Location Ponceletas, PR	Subject Drainage Swales
Preparer's Initials JAL	Date 9/2/94	Reviewer's Initials MLP	Date 9/21/94

Check Reach "B" Spreadsheet for $S = 3.3\%$, $d = 0.74$



$$A = 4(0.74) + (0.74)(3(0.74))$$

$$A = 2.96 + 1.64$$

$$A = 4.6$$

$$P = 4 + 2(\sqrt{0.74^2 + (3(0.74))^2})$$

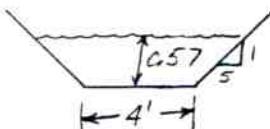
$$P = 8.68$$

$$Q = 4.6 \left(\frac{1.49}{0.035} \right) \left(\frac{4.6}{8.68} \right)^{2/3} (0.033)^{1/2}$$

$$Q = (4.6)(42.57)(0.65)(0.18)$$

$$Q = 23.25 \text{ OK}$$

Check Reach "B" Spreadsheet for $S = 8\%$, $d = 0.57$



$$A = 4(0.57) + (5(0.57))(0.57)$$

$$A = 3.90$$

$$P = 4 + 2(\sqrt{0.57^2 + (5(0.57))^2})$$

$$P = 9.81$$

$$Q = 3.9 \left(\frac{1.49}{0.035} \right) \left(\frac{3.9}{9.81} \right)^{2/3} (0.08)^{1/2}$$

$$Q = 3.9 (42.57) (0.54) (.28)$$

$$Q = 25.36 \text{ OK}$$



COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

OHM Corporation

Page 5 of 29

Proj. No. <u>16139</u>	Client <u>PROTECO</u>	Location <u>Puerto Rico</u>	Subject <u>Drainage Swales</u>
Preparer's Initials <u>JAL</u>	Date <u>9/2/94</u>	Reviewer's Initials <u>MLP</u>	Date <u>9/21/94</u>

Reach "C" Drainage Swale

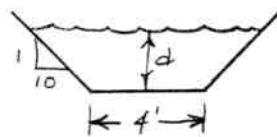
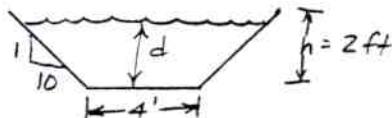
Check Min. Slope section for capacity

$$Q = 20.3 \text{ cfs}, \text{ assume } n = 0.035 \quad \text{Min. } S = \frac{2}{43} = 4.7\%$$

Determine flow depth

$$A = 4(d) + (10d)(d)$$

$$P = 4 + \sqrt{d^2 + (10d)^2} (2)$$



$$\text{Max. } S = \frac{2}{28} = 7.1\%$$

From Reach "C" 4.7% slope spreadsheet,

Flow depth ≈ 0.48 ft, channel depth = 2'

∴ Channel depth sufficient

Determine flow velocity for rip rap sizing at max. slope

$$\text{Max. } S = 7.1\%$$

$$R_H = \frac{A}{P} = \frac{4d + (10d)(d)}{4 + \sqrt{d^2 + (10d)^2}}$$

$$V = \frac{1.49}{0.035} \left(\frac{4d + (10d)(d)}{4 + \sqrt{d^2 + (10d)^2}} \right)^{3/2} (0.071)^{1/2}$$

From Reach "C" 7.1% slope spreadsheet, $V \approx 5.1$ fps

∴ Use R-3 rip rap

Check $n = 0.031$ for velocity of 20.3 cfsFrom spreadsheet w/ $n = 0.031$, $S = 7.1\%$, velocity ≈ 5.5 fps ok

PROTECO LANDFILL
REACH "C" DRAINAGE CALCULATIONS

FOR SLOPE = 4.7%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.98	0.031	0.047	0.1	0.50	6.01	1.97
3.48	0.031	0.047	0.2	1.20	8.08	2.90
7.68	0.031	0.047	0.3	2.10	10.03	3.66
13.72	0.031	0.047	0.4	3.20	12.04	4.29
18.34	0.031	0.047	0.46	3.96	13.25	4.64
19.19	0.031	0.047	0.47	4.09	13.45	4.69
20.06	0.031	0.047	0.48	4.22	13.65	4.75
20.95	0.031	0.047	0.49	4.36	13.85	4.80
21.87	0.031	0.047	0.5	4.50	14.05	4.86
32.33	0.031	0.047	0.6	6.00	16.06	5.39
45.31	0.031	0.047	0.7	7.70	18.07	5.88
61.01	0.031	0.047	0.8	9.60	20.08	6.36
79.64	0.031	0.047	0.9	11.70	22.09	6.81
101.38	0.031	0.047	1	14.00	24.10	7.24
126.42	0.031	0.047	1.1	16.50	26.11	7.66
154.93	0.031	0.047	1.2	19.20	28.12	8.07
187.10	0.031	0.047	1.3	22.10	30.13	8.47

PROTECO LANDFILL
REACH "C" DRAINAGE CALCULATIONS

FOR SLOPE = 7.1%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
1.07	0.035	0.071	0.1	0.50	6.01	2.14
3.79	0.035	0.071	0.2	1.20	8.08	3.16
8.36	0.035	0.071	0.3	2.10	10.03	3.98
14.94	0.035	0.071	0.4	3.20	12.04	4.67
19.97	0.035	0.071	0.48	3.96	13.25	5.05
20.89	0.035	0.071	0.47	4.09	13.45	5.11
21.84	0.035	0.071	0.48	4.22	13.65	5.17
22.81	0.035	0.071	0.49	4.36	13.85	5.23
23.81	0.035	0.071	0.5	4.50	14.05	5.29
35.19	0.035	0.071	0.6	6.00	16.06	5.86
43.32	0.035	0.071	0.66	7.00	17.27	6.19
44.78	0.035	0.071	0.67	7.17	17.47	6.25
46.26	0.035	0.071	0.68	7.34	17.67	6.30
47.78	0.035	0.071	0.69	7.52	17.87	6.35
49.32	0.035	0.071	0.7	7.70	18.07	6.41
66.42	0.035	0.071	0.8	9.60	20.08	6.92
86.70	0.035	0.071	0.9	11.70	22.09	7.41
110.37	0.035	0.071	1	14.00	24.10	7.88
137.62	0.035	0.071	1.1	16.50	26.11	8.34
168.66	0.035	0.071	1.2	19.20	28.12	8.78
203.68	0.035	0.071	1.3	22.10	30.13	9.22

PROTECO LANDFILL
REACH "C" DRAINAGE CALCULATIONS

FOR SLOPE = 7.1%, n=0.031

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
1.21	0.031	0.071	0.1	0.50	6.01	2.42
4.28	0.031	0.071	0.2	1.20	8.08	3.57
9.43	0.031	0.071	0.3	2.10	10.03	4.49
16.87	0.031	0.071	0.4	3.20	12.04	5.27
18.65	0.031	0.071	0.42	3.44	12.44	5.42
19.59	0.031	0.071	0.43	3.57	12.64	5.49
20.55	0.031	0.071	0.44	3.70	12.84	5.56
21.53	0.031	0.071	0.45	3.83	13.04	5.63
26.88	0.031	0.071	0.5	4.50	14.05	5.97
39.73	0.031	0.071	0.6	6.00	16.06	6.62
48.91	0.031	0.071	0.66	7.00	17.27	6.99
50.56	0.031	0.071	0.67	7.17	17.47	7.05
52.23	0.031	0.071	0.68	7.34	17.67	7.11
53.94	0.031	0.071	0.69	7.52	17.87	7.17
55.68	0.031	0.071	0.7	7.70	18.07	7.23
74.99	0.031	0.071	0.8	9.60	20.08	7.81
97.88	0.031	0.071	0.9	11.70	22.09	8.37
124.61	0.031	0.071	1	14.00	24.10	8.90
155.38	0.031	0.071	1.1	16.50	26.11	9.42
190.43	0.031	0.071	1.2	19.20	28.12	9.92
229.97	0.031	0.071	1.3	22.10	30.13	10.41



OHM Corporation

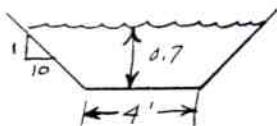
COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 6 of 29

Proj. No. <u>16139</u>	Client <u>PROTECO</u>	Location <u>Puerto Rico</u>	Subject <u>Drainage Swales</u>
Preparer's Initials <u>JAL</u>	Date <u>9/6/94</u>	Reviewer's Initials <u>MLP</u>	Date <u>9/21/94</u>

Check Leach "C" spreadsheet for $S = 4.7\%$, $n = 0.031$, $d = 0.7$



$$A = 4(0.7) + (10(0.7))(0.7)$$

$$A = 2.8 + 7.7$$

$$A = 7.7 \quad \underline{\text{OK}}$$

$$P = 4 + \left(\sqrt{(0.7)^2 + (10(0.7))^2}\right)(2)$$

$$P = 4 + (2.03)(2)$$

$$P = 18.06 \quad \underline{\text{OK}}$$

$$Q = (7.7) \left(\frac{1.49}{0.031}\right) \left(\frac{7.7}{18.06}\right)^{2/3} (0.047)^{1/2}$$

$$Q = (7.7) (48.06) (0.56) (0.22)$$

$$Q = 45.45 \text{ cfs} \quad \underline{\text{OK}}$$



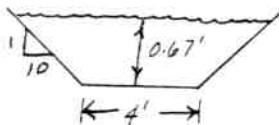
OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Proj. No.	Client	Location	Subject
16139	PROTECO	Ponceletas, PR	Drainage Swales
Preparer's Initials	Date	Reviewer's Initials	Date
JAL	9/6/94	MLP	9/21/94

Check Reach "C" spreadsheet for $S = 7.1\%$, $n = 0.035$, $d = 0.67$



$$A = 4(0.67) + (10(0.67))(0.67)$$

$$A = 2.68 + 4.49$$

$$A = 7.17 \text{ ok}$$

$$P = 4 + \sqrt{(0.67)^2 + (10(0.67))^2} (2)$$

$$P = 4 + 2(6.73)$$

$$P = 17.47$$

$$Q = \frac{1.49}{0.035} \left(\frac{7.17}{17.47} \right)^{0.67} (0.071)^{1/2} (7.17)$$

$$Q = 42.57 (0.55) (0.27) (7.17)$$

$$Q = 44.78 \text{ cfs ok}$$

Reach "D" Drainage Swale

Check Min. Slope section for capacity, assume $n = 0.035$

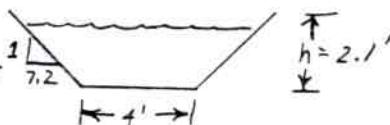
$$A = 4(d) + (d)(7.2d)$$

$$P = 4 + 2\sqrt{d^2 + (7.2d)^2}$$

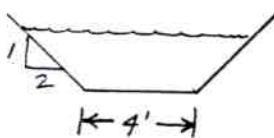
$$Q = Q_{\text{Reach A}} + Q_{\text{Reach B}} + Q_{\text{Reach D}}$$

$$Q = 5.6 \text{ cfs} + 19.1 \text{ cfs} + 3.6 \text{ cfs}$$

$$Q = 28.3 \text{ cfs}$$



$$\text{Min. } S = \frac{2}{68} = 2.9\%$$



$$\text{Max. } S = \frac{2}{15} = 13.3\%$$



OHM Corporation

COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Proj. No.	Client	Location	Subject
16139	PROTECO	Penuelas, P.R.	Drainage Surfaces
Preparer's Initials	Date	Reviewer's Initials	Date
JAL	9/6/94	MLP	9/21/94
Approver's Initials	Date		

From Reach "D" Spreadsheet w/ $S = 2.9\%$,

Flow Depth ≈ 0.72 ft ok

Determine velocity for rip rap sizing at Max. S

$$A = 4(d) + (d)(2d)$$

$$P = 4 + 2\sqrt{d^2 + (2d)^2}$$

From Reach "D" Spreadsheet w/ $S = 13.3\%$,

Velocity ≈ 9.2 fps

\therefore Use R-5 rip-rap

Max. = 18" $D_{30} = 9"$ Min. = 5"

Check Reach "D" Spreadsheet for $S = 2.9\%$, $d = 0.92$ ft

$$A = 4(0.92) + (0.92)(7.2(0.92))$$

$$A = 3.68 + 6.09$$

$$A = 9.77 \quad \underline{\text{ok}}$$

$$P = 4 + (2)\sqrt{0.92^2 + (7.2(0.92))^2}$$

$$P = 4 + 13.38$$

$$P = 17.38 \quad \underline{\text{ok}}$$

PROTECO LANDFILL
REACH "D" DRAINAGE CALCULATIONS

FOR SLOPE = 2.9%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.66	0.035	0.029	0.1	0.47	5.45	1.41
2.29	0.035	0.029	0.2	1.09	6.91	2.10
4.87	0.035	0.029	0.3	1.85	8.36	2.64
8.51	0.035	0.029	0.4	2.75	9.82	3.09
13.30	0.035	0.029	0.5	3.80	11.27	3.50
19.34	0.035	0.029	0.6	4.99	12.72	3.87
26.72	0.035	0.029	0.7	6.33	14.18	4.22
27.54	0.035	0.029	0.71	6.47	14.32	4.26
28.37	0.035	0.029	0.72	6.61	14.47	4.29
29.22	0.035	0.029	0.73	6.76	14.61	4.32
30.08	0.035	0.029	0.74	6.90	14.76	4.36
35.55	0.035	0.029	0.8	7.81	15.63	4.55
45.93	0.035	0.029	0.9	9.43	17.08	4.87
47.05	0.035	0.029	0.91	9.60	17.23	4.90
48.19	0.035	0.029	0.92	9.77	17.38	4.93
49.35	0.035	0.029	0.93	9.95	17.52	4.96
50.53	0.035	0.029	0.94	10.12	17.67	4.99
57.93	0.035	0.029	1	11.20	18.54	5.17
71.66	0.035	0.029	1.1	13.11	19.99	5.46
87.19	0.035	0.029	1.2	15.17	21.45	5.75
104.62	0.035	0.029	1.3	17.37	22.90	6.02

PROTECO LANDFILL
REACH "D" DRAINAGE CALCULATIONS

FOR SLOPE = 13.3%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
1.34	0.035	0.133	0.1	0.42	4.45	3.19
4.33	0.035	0.133	0.2	0.88	4.89	4.92
8.65	0.035	0.133	0.3	1.38	5.34	6.27
14.23	0.035	0.133	0.4	1.92	5.79	7.41
21.04	0.035	0.133	0.5	2.50	6.24	8.42
26.54	0.035	0.133	0.57	2.93	6.55	9.06
27.37	0.035	0.133	0.58	2.99	6.59	9.15
28.22	0.035	0.133	0.59	3.06	6.64	9.23
29.08	0.035	0.133	0.6	3.12	6.68	9.32
38.36	0.035	0.133	0.7	3.78	7.13	10.15
45.61	0.035	0.133	0.77	4.27	7.44	10.69
46.70	0.035	0.133	0.78	4.34	7.49	10.77
47.80	0.035	0.133	0.79	4.41	7.53	10.84
48.91	0.035	0.133	0.8	4.48	7.58	10.92
60.75	0.035	0.133	0.9	5.22	8.02	11.64
73.93	0.035	0.133	1	6.00	8.47	12.32
88.46	0.035	0.133	1.1	6.82	8.92	12.97
104.39	0.035	0.133	1.2	7.68	9.37	13.59
121.74	0.035	0.133	1.3	8.58	9.81	14.19



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page 9 of 29

Proj. No. <u>16139</u>	Client <u>PROTECO</u>	Location <u>Poncelet, P.R.</u>	Subject <u>Drainage Swales</u>
Preparer's Initials <u>JAL</u>	Date <u>9/6/94</u>	Reviewer's Initials <u>MLP</u>	Date <u>9/21/94</u>

$$Q = 9.77 \left(\frac{1.49}{0.035} \right) \left(\frac{9.77}{17.38} \right)^{3/5} (0.029)^{1/2}$$

$$Q = 9.77 (42.57) (0.68) (0.17)$$

$$Q = 48.16 \text{ cfs } \underline{\text{OK}}$$

Check Reach "D" spreadsheet for $S=13.3\%$, $d = 0.8 \text{ ft}$

$$A = 4(d) + (d)(2d)$$

$$A = 4(0.8) + (0.8)(2(0.8))$$

$$A = 3.2 + 1.28$$

$$A = 4.48 \underline{\text{OK}}$$

$$P = 4 + 2 \left(\sqrt{(0.8)^2 + (2(0.8))^2} \right)$$

$$P = 4 + 3.58$$

$$P = 7.58 \underline{\text{OK}}$$

$$Q = 4.48 \left(\frac{1.49}{0.035} \right) \left(\frac{4.48}{7.58} \right)^{0.67} (0.133)^{1/2}$$

$$Q = 4.48 (42.57) (0.7) (0.36)$$

$$Q = 48.69 \underline{\text{OK}}$$

For R-5 rip rap, $n = 0.038 \therefore$ confirm adequate channel capacity at min. slope. From spreadsheet w/ $S = 2.9\%$ & $n = 0.038$, flow depth @ 28.5 cfs $\approx 0.75 \text{ ft} \therefore$ channel design adequate.

PROTECO LANDFILL
REACH "D" DRAINAGE CALCULATIONS

FOR SLOPE = 2.9%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.61	0.038	0.029	0.1	0.47	5.45	1.30
2.11	0.038	0.029	0.2	1.09	6.91	1.94
4.49	0.038	0.029	0.3	1.85	8.36	2.43
7.84	0.038	0.029	0.4	2.75	9.82	2.85
12.25	0.038	0.029	0.5	3.80	11.27	3.22
17.81	0.038	0.029	0.6	4.99	12.72	3.57
24.61	0.038	0.029	0.7	6.33	14.18	3.89
26.91	0.038	0.029	0.73	6.76	14.61	3.98
27.70	0.038	0.029	0.74	6.90	14.76	4.01
28.51	0.038	0.029	0.75	7.05	14.90	4.04
29.33	0.038	0.029	0.76	7.20	15.05	4.07
32.75	0.038	0.029	0.8	7.81	15.63	4.19
42.30	0.038	0.029	0.9	9.43	17.08	4.48
47.64	0.038	0.029	0.95	10.30	17.81	4.63
48.75	0.038	0.029	0.96	10.48	17.96	4.65
49.88	0.038	0.029	0.97	10.65	18.10	4.68
51.02	0.038	0.029	0.98	10.83	18.25	4.71
53.36	0.038	0.029	1	11.20	18.54	4.76
66.00	0.038	0.029	1.1	13.11	19.99	5.03
80.31	0.038	0.029	1.2	15.17	21.45	5.29
96.36	0.038	0.029	1.3	17.37	22.90	5.55



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

						Page <u>10</u> of <u>29</u>
Proj. No.	Client	Location	Subject			
16139	PROTECO	Poncelet, P.R.				
Preparer's Initials	JAL	Date 9/7/94	Reviewer's Initials MLP	Date 9/21/94	Approver's Initials	Date

Reach "E" Drainage Swale

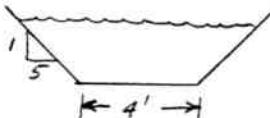
Check Min. Slope sections for capacity

assume $n = 0.035$

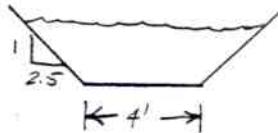
$$Q = 0.9 \text{ cfs}$$

$$A = 4(d) + d(5d)$$

$$P = 4 + (2)\sqrt{d^2 + (5d)^2}$$



$$\text{Min. } S = \frac{2'}{117'} = 1.7\%$$



$$\text{Max. } S = \frac{2'}{17} = 11.8\%$$

From Reach "E" spreadsheet w/ $S = 1.7\%$ Flow Depth $\approx 0.14 \text{ ft}$ ok

Determine velocity for rip-rap sizing at Max. S

$$A = 4(d) + d(2.5d)$$

$$P = 4 + \sqrt{d^2 + (2.5d)^2} \quad (2)$$

From Reach "E" spreadsheet w/ $S = 11.8\%$ velocity @ $Q = 0.9 \text{ cfs} = 26 \text{ fps}$ \therefore L-2 rip-rap permissible $n = 0.028$

PROTECO LANDFILL
REACH "E" DRAINAGE CALCULATIONS

FOR SLOPE = 1.7%, n = 0.035

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.50	0.035	0.017	0.1	0.45	5.02	1.10
0.58	0.035	0.017	0.11	0.50	5.12	1.17
0.68	0.035	0.017	0.12	0.55	5.22	1.23
0.78	0.035	0.017	0.13	0.60	5.33	1.29
0.89	0.035	0.017	0.14	0.66	5.43	1.35
1.66	0.035	0.017	0.2	1.00	6.04	1.66
3.46	0.035	0.017	0.3	1.65	7.06	2.10
5.91	0.035	0.017	0.4	2.40	8.08	2.46
9.05	0.035	0.017	0.5	3.25	9.10	2.78
12.93	0.035	0.017	0.6	4.20	10.12	3.08
17.60	0.035	0.017	0.7	5.25	11.14	3.35
23.11	0.035	0.017	0.8	6.40	12.16	3.61
29.50	0.035	0.017	0.9	7.65	13.18	3.86
36.81	0.035	0.017	1	9.00	14.20	4.09
45.09	0.035	0.017	1.1	10.45	15.22	4.31
54.39	0.035	0.017	1.2	12.00	16.24	4.53
64.75	0.035	0.017	1.3	13.65	17.26	4.74

PROTECO LANDFILL
REACH "E" DRAINAGE CALCULATIONS

FOR SLOPE = 11.8%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.54	0.035	0.118	0.06	0.25	4.32	2.16
0.70	0.035	0.118	0.07	0.29	4.38	2.39
0.87	0.035	0.118	0.08	0.34	4.43	2.60
1.06	0.035	0.118	0.09	0.38	4.48	2.80
1.27	0.035	0.118	0.1	0.43	4.54	2.99
4.13	0.035	0.118	0.2	0.90	5.08	4.59
8.31	0.035	0.118	0.3	1.43	5.62	5.83
13.77	0.035	0.118	0.4	2.00	6.15	6.89
20.50	0.035	0.118	0.5	2.63	6.69	7.81
28.53	0.035	0.118	0.6	3.30	7.23	8.65
37.88	0.035	0.118	0.7	4.03	7.77	9.41
48.60	0.035	0.118	0.8	4.80	8.31	10.13
60.73	0.035	0.118	0.9	5.63	8.85	10.80
74.32	0.035	0.118	1	6.50	9.39	11.43
89.40	0.035	0.118	1.1	7.43	9.92	12.04
106.04	0.035	0.118	1.2	8.40	10.46	12.62
124.27	0.035	0.118	1.3	9.43	11.00	13.18



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

						Page <u>11</u> of <u>29</u>
Proj. No.	Client	Location		Subject		
16139	PROTECO		Ponceletas, P.R.		Drainage Juntas	
Preparer's Initials	JAL	Date 9/7/94	Reviewer's Initials MLP	Date 9/21/94	Approver's Initials	Date

Check reach "E" maximum flow depth & velocity
 for $n = 0.028$

From spreadsheet for $S = 1.7\%$

Flow depth ≈ 0.13 ft ok

From spreadsheet for $S = 11.8\%$

Velocity ≈ 3 fps ok

∴ Either R-2 or R-4 rip rap acceptable for use

Graded Rock Size

NSA No.	Max.	D_{50}	Min.	n
R-2	3"	1.5"	1"	0.028
R-4	12"	6"	3"	0.035

Check reach "E" spreadsheet for $S = 1.7\%$, $d = 0.13$, $n = 0.028$

$$A = 4(0.13) + 0.13(5(0.13))$$

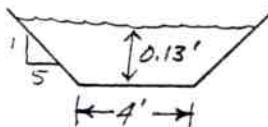
$$A = 0.6 \text{ ft}^2$$

$$P = 4 + \sqrt{(0.13)^2 + (5(0.13))^2} \quad (2)$$

$$P = 5.33 \text{ ft}$$

$$Q = (0.6) \left(\frac{1.49}{0.028} \right) \left(\frac{0.6}{5.33} \right)^{0.67} (0.017)^{1/2}$$

$$Q = (0.6)(53.21)(.23)(0.13) = 0.95 \text{ cfs } \underline{\text{ok}}$$



PROTECO LANDFILL
REACH "E" DRAINAGE CALCULATIONS

FOR SLOPE = 1.7%, n = 0.028

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.62	0.028	0.017	0.1	0.45	5.02	1.38
0.73	0.028	0.017	0.11	0.50	5.12	1.46
0.85	0.028	0.017	0.12	0.55	5.22	1.54
0.98	0.028	0.017	0.13	0.60	5.33	1.61
1.11	0.028	0.017	0.14	0.66	5.43	1.69
2.08	0.028	0.017	0.2	1.00	6.04	2.08
4.32	0.028	0.017	0.3	1.65	7.06	2.62
7.38	0.028	0.017	0.4	2.40	8.08	3.08
11.31	0.028	0.017	0.5	3.25	9.10	3.48
16.17	0.028	0.017	0.6	4.20	10.12	3.85
22.01	0.028	0.017	0.7	5.25	11.14	4.19
28.89	0.028	0.017	0.8	6.40	12.16	4.51
36.87	0.028	0.017	0.9	7.65	13.18	4.82
46.01	0.028	0.017	1	9.00	14.20	5.11
56.36	0.028	0.017	1.1	10.45	15.22	5.39
67.99	0.028	0.017	1.2	12.00	16.24	5.67
80.94	0.028	0.017	1.3	13.65	17.26	5.93

PROTECO LANDFILL
REACH "E" DRAINAGE CALCULATIONS

FOR SLOPE = 11.8%, n = 0.028

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter	Velocity (fps)
0.67	0.028	0.118	0.06	0.25	4.32	2.70
0.87	0.028	0.118	0.07	0.29	4.38	2.98
1.09	0.028	0.118	0.08	0.34	4.43	3.25
1.33	0.028	0.118	0.09	0.38	4.48	3.50
1.59	0.028	0.118	0.1	0.43	4.54	3.74
5.16	0.028	0.118	0.2	0.90	5.08	5.74
10.39	0.028	0.118	0.3	1.43	5.62	7.29
17.22	0.028	0.118	0.4	2.00	6.15	8.61
25.63	0.028	0.118	0.5	2.63	6.69	9.76
35.66	0.028	0.118	0.6	3.30	7.23	10.81
47.35	0.028	0.118	0.7	4.03	7.77	11.77
60.75	0.028	0.118	0.8	4.80	8.31	12.66
75.92	0.028	0.118	0.9	5.63	8.85	13.50
92.90	0.028	0.118	1	6.50	9.39	14.29
111.75	0.028	0.118	1.1	7.43	9.92	15.05
132.55	0.028	0.118	1.2	8.40	10.46	15.78
155.33	0.028	0.118	1.3	9.43	11.00	16.48



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

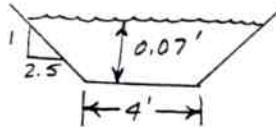
						Page <u>12</u> of <u>29</u>
Proj. No.	Client	Location	Subject			
16139	PROTECO	Ponceletas, P.R.	Preparer's Initials	JAL	Date 9/7/94	Reviewer's Initials MLP Date 9/21/94 Approver's Initials Date

Check Reach "E" spreadsheet for $S = 11.8\%$, $d = 0.07$, $n = 0.028$

$$A = 4(0.07) + 0.07(2.5(0.07))$$

$$A = 0.28 + 0.01$$

$$A = 0.29$$



$$P = 4 + (2) \sqrt{0.07^2 + (2.5(0.07))^2}$$

$$P = 4 + 0.38$$

$$P = 4.38$$

$$Q = 0.29 \left(\frac{1.49}{0.028} \right) \left(\frac{0.29}{4.38} \right)^{0.67} (0.118)^{\frac{1}{2}}$$

$$Q = 0.29 (53.21) (0.16) (0.34)$$

$$Q = 0.84 \text{ cfs } \underline{\text{ok}}$$

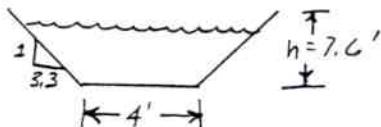
Reach "F" Drainage Swale

Check Min. slope for capacity, assume $n = 0.035$

$$A = 4(d) + d(3.3(d))$$

$$P = 4 + (2) \sqrt{d^2 + (3.3(d))^2}$$

$$Q = 18 \text{ cfs}$$

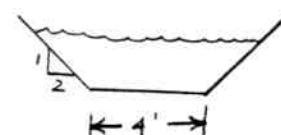


$$\text{Min. } S = \frac{2}{41} = 4.9\%$$

From Reach "F" spreadsheet w/s = 4.9%

$$\text{Flow depth } \bar{h} = 0.58 \text{ ft}$$

\therefore Channel depth sufficient



$$\text{Max. } S = \frac{2}{10} = 20\%$$



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08-89

						Page <u>13</u> of <u>29</u>
Proj. No.	Client	Location	Subject			
16139	PROTECO	Poncelet, P.R.				Drainage Swales
Preparer's Initials	JAL	Date 9/7/94	Reviewer's Initials MLP	Date 9/21/94	Approver's Initials	Date

Determine velocity for rip-rap sizing at Mar. 5

$$A = 4d + (2d)d$$

$$P = 4 + (2) \sqrt{d^2 + (2d)^2}$$

From Reach "F" spreadsheet w/ $s = 20\%$

$$\text{Velocity} \approx 9.2 \text{ fps}$$

\therefore Use L-5 rip-rap

Mar.	D_{50}	Min.
18"	9"	5"

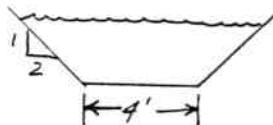
Since increased slope occurs over very short distance, divide Reach "F" into two sub-reaches, "F-1" and "F-2". This will enable use of smaller rip rap more commonly used in drainage channels on site, allowing bulk purchase of rip-rap.

$$\text{Max slope Reach "F-1"} = \frac{s}{D_{50}} = \frac{20}{18} = 6.7\%$$

Calculate velocity for rip-rap sizing

$$A = 4d + (2d)(d)$$

$$P = 4 + (2) \sqrt{d^2 + (2d)^2}$$



PROTECO LANDFILL
REACH "F" DRAINAGE CALCULATIONS

FOR SLOPE = 4.9%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
0.83	0.035	0.049	0.1	0.43	4.69	1.91
2.71	0.035	0.049	0.2	0.93	5.38	2.91
5.52	0.035	0.049	0.3	1.50	6.07	3.69
9.25	0.035	0.049	0.4	2.13	6.76	4.34
13.90	0.035	0.049	0.5	2.83	7.45	4.92
17.16	0.035	0.049	0.56	3.27	7.86	5.24
17.74	0.035	0.049	0.57	3.35	7.93	5.29
18.33	0.035	0.049	0.58	3.43	8.00	5.34
18.93	0.035	0.049	0.59	3.51	8.07	5.39
19.53	0.035	0.049	0.6	3.59	8.14	5.44
26.17	0.035	0.049	0.7	4.42	8.83	5.93
33.87	0.035	0.049	0.8	5.31	9.52	6.38
42.66	0.035	0.049	0.9	6.27	10.21	6.80
52.60	0.035	0.049	1	7.30	10.90	7.21
63.73	0.035	0.049	1.1	8.39	11.59	7.59
76.09	0.035	0.049	1.2	9.55	12.28	7.97
89.73	0.035	0.049	1.3	10.78	12.97	8.33

PROTECO LANDFILL
REACH "F" DRAINAGE CALCULATIONS

FOR SLOPE = 20%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
1.65	0.035	0.2	0.1	0.42	4.45	3.92
5.31	0.035	0.2	0.2	0.88	4.89	6.03
10.61	0.035	0.2	0.3	1.38	5.34	7.69
17.45	0.035	0.2	0.4	1.92	5.79	9.09
18.22	0.035	0.2	0.41	1.98	5.83	9.22
19.00	0.035	0.2	0.42	2.03	5.88	9.35
19.80	0.035	0.2	0.43	2.09	5.92	9.47
20.61	0.035	0.2	0.44	2.15	5.97	9.60
25.80	0.035	0.2	0.5	2.50	6.24	10.32
35.66	0.035	0.2	0.6	3.12	6.68	11.43
47.04	0.035	0.2	0.7	3.78	7.13	12.44
59.98	0.035	0.2	0.8	4.48	7.58	13.39
74.50	0.035	0.2	0.9	5.22	8.02	14.27
90.65	0.035	0.2	1	6.00	8.47	15.11
108.48	0.035	0.2	1.1	6.82	8.92	15.91
128.01	0.035	0.2	1.2	7.68	9.37	16.67
149.29	0.035	0.2	1.3	8.58	9.81	17.40



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page	<u>14</u>	of <u>29</u>
------	-----------	--------------

Proj. No.	Client	Location	Subject
16139	PROTECO	Ponceletas, P.R.	Drainage Swales
Preparer's Initials	Date	Reviewer's Initials	Approver's Initials Date

From Reach "F-1" spreadsheet w/ $S = 6.7\%$

$$\text{velocity} \approx 6.3 \text{ fps}$$

\therefore L-4 rip rap suitable for Reach "F-1"

Check Reach "F" spreadsheet for $S = 4.9\%$, $d = 0.58$

$$A = 4(0.58) + 0.58(3.3(0.58))$$

$$A = 2.32 + 1.11 = 3.43$$

$$P = 4 + (2) \sqrt{0.58^2 + (3.3(0.58))^2}$$

$$P = 4 + 4$$

$$P = 8$$

$$Q = 3.43 \left(\frac{1.49}{0.035}\right) \left(\frac{3.43}{8}\right)^{\frac{2}{3}} (0.049)^{\frac{1}{2}}$$

$$Q = 3.43(42.57)(0.57)(0.22)$$

$$Q = 18.31 \text{ cfs } \underline{\text{OK}}$$

Check Reach "F" spreadsheet for $S = 20\%$, $d = 0.41$

$$A = 4(0.41) + 0.41(2(0.41))$$

$$A = 1.64 + 0.34 = 1.98 \text{ ft}^2 \underline{\text{OK}}$$

$$P = 4 + (2) \sqrt{0.41^2 + (2(0.41))^2}$$

$$P = 4 + 1.83$$

$$P = 5.83 \underline{\text{OK}}$$

PROTECO LANDFILL
REACH "F-1" DRAINAGE CALCULATIONS

SLOPE = 6.7%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
0.95	0.035	0.067	0.1	0.42	4.45	2.27
3.07	0.035	0.067	0.2	0.88	4.89	3.49
6.14	0.035	0.067	0.3	1.38	5.34	4.45
10.10	0.035	0.067	0.4	1.92	5.79	5.26
14.93	0.035	0.067	0.5	2.50	6.24	5.97
17.68	0.035	0.067	0.55	2.81	6.46	6.30
18.25	0.035	0.067	0.56	2.87	6.50	6.37
18.83	0.035	0.067	0.57	2.93	6.55	6.43
19.43	0.035	0.067	0.58	2.99	6.59	6.49
20.64	0.035	0.067	0.6	3.12	6.68	6.61
27.23	0.035	0.067	0.7	3.78	7.13	7.20
34.71	0.035	0.067	0.8	4.48	7.58	7.75
43.12	0.035	0.067	0.9	5.22	8.02	8.26
52.47	0.035	0.067	1	6.00	8.47	8.75
62.78	0.035	0.067	1.1	6.82	8.92	9.21
74.09	0.035	0.067	1.2	7.68	9.37	9.65
86.41	0.035	0.067	1.3	8.58	9.81	10.07



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page 15 of 29

Proj. No.	Client	Location	Subject
16139	PROTECO	Puerto Rico	Drainage Swales
Preparer's Initials	Date	Reviewer's Initials	Approver's Initials

Reach "F", $s = 20\%$, $d = 0.41$ (cont'd)

$$Q = 1.98 \left(\frac{1.49}{0.035} \right) \left(\frac{1.98}{5.83} \right)^{\frac{2}{3}} (0.2)^{\frac{1}{2}}$$

$$Q = 1.98 (42.57) (0.49) (0.45)$$

$$Q = 18.28 \text{ cfs } \underline{\text{OK}}$$

Check Reach "F-1" spreadsheet for $s = 6.7\%$, $d = 0.56$

$$A = 4d + d(2d)$$

$$A = 4(0.56) + 0.56(2(0.56))$$

$$A = 2.87 \text{ ft}^2$$

$$P = 4 + (2) \sqrt{(0.56)^2 + ((2)0.56)^2}$$

$$P = 6.5$$

$$Q = 2.87 \left(\frac{1.49}{0.035} \right) \left(\frac{2.87}{6.5} \right)^{\frac{2}{3}} (0.067)^{\frac{1}{2}}$$

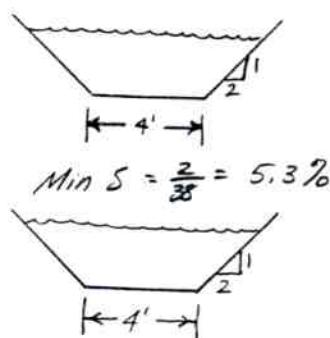
$$Q = 2.87 (42.57) (0.58) (0.24)$$

$$Q = 18.34 \text{ cfs } \underline{\text{OK}}$$

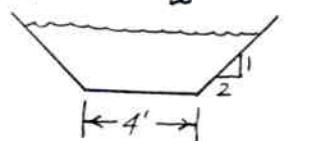
Reach "G" Drainage Swale

Check Min Slope section for capacity

$$Q = 37.4 \text{ cfs}$$



$$\text{Min } S = \frac{2}{28} = 5.3\%$$



$$\text{Max } S = \frac{2}{14} = 14.3\%$$



OHM Corporation

COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Proj. No.	Client	Location	Subject
16139	PROTECO	Poncelet, P.R.	Drainage Swales
Preparer's Initials	Date	Reviewer's Initials	Date
JAL	9/8/94	MLP	9/21/94

Reach "G" (cont'd)

$$A = 4d + d(2(d))$$

$$P = 4 + (2) \sqrt{d^2 + (2(d))^2}$$

From Reach "G" spreadsheet w/ $S = 5.3\%$

Flow depth $\approx 0.89'$; Channel depth = 7' OK

Determine velocity at maximum slope for riprap sizing

$$A = 4(d) + (2d)(d)$$

$$P = 4 + (2) \sqrt{d^2 + (2d)^2}$$

From Reach "G" spreadsheet w/ $S = 14.3\%$

Velocity ≈ 10.3 fps

\therefore Use R-5 rip rap $n = 0.038$

Check Flow depth for $n = 0.038$

From spreadsheet w/ slope = 5.3%, $n = 0.038$

Flow depth $\approx 1'$ OK

Check velocity for slope = 14.3%, $n = 0.038$

Velocity = 9.7 fps OK

PROTECO LANDFILL
REACH "G" DRAINAGE CALCULATIONS

SLOPE = 5.3%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
0.85	0.035	0.053	0.1	0.42	4.45	2.02
2.73	0.035	0.053	0.2	0.88	4.89	3.10
5.46	0.035	0.053	0.3	1.38	5.34	3.96
8.98	0.035	0.053	0.4	1.92	5.79	4.68
13.28	0.035	0.053	0.5	2.50	6.24	5.31
18.35	0.035	0.053	0.6	3.12	6.68	5.88
24.21	0.035	0.053	0.7	3.78	7.13	6.41
30.87	0.035	0.053	0.8	4.48	7.58	6.89
35.26	0.035	0.053	0.86	4.92	7.85	7.17
36.02	0.035	0.053	0.87	4.99	7.89	7.21
36.79	0.035	0.053	0.88	5.07	7.94	7.26
37.57	0.035	0.053	0.89	5.14	7.98	7.30
38.35	0.035	0.053	0.9	5.22	8.02	7.35
46.67	0.035	0.053	1	6.00	8.47	7.78
55.84	0.035	0.053	1.1	6.82	8.92	8.19
65.89	0.035	0.053	1.2	7.68	9.37	8.58
76.85	0.035	0.053	1.3	8.58	9.81	8.96

PROTECO LANDFILL
REACH "G" DRAINAGE CALCULATIONS

SLOPE = 14.3%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
1.39	0.035	0.143	0.1	0.42	4.45	3.31
4.49	0.035	0.143	0.2	0.88	4.89	5.10
8.97	0.035	0.143	0.3	1.38	5.34	6.50
14.76	0.035	0.143	0.4	1.92	5.79	7.69
21.82	0.035	0.143	0.5	2.50	6.24	8.73
30.15	0.035	0.143	0.6	3.12	6.68	9.66
35.77	0.035	0.143	0.66	3.51	6.95	10.19
36.75	0.035	0.143	0.67	3.58	7.00	10.27
37.75	0.035	0.143	0.68	3.64	7.04	10.36
38.75	0.035	0.143	0.69	3.71	7.09	10.44
39.77	0.035	0.143	0.7	3.78	7.13	10.52
50.71	0.035	0.143	0.8	4.48	7.58	11.32
57.92	0.035	0.143	0.86	4.92	7.85	11.77
59.17	0.035	0.143	0.87	4.99	7.89	11.85
60.43	0.035	0.143	0.88	5.07	7.94	11.92
61.71	0.035	0.143	0.89	5.14	7.98	12.00
63.00	0.035	0.143	0.9	5.22	8.02	12.07
76.66	0.035	0.143	1	6.00	8.47	12.78
91.72	0.035	0.143	1.1	6.82	8.92	13.45
108.24	0.035	0.143	1.2	7.68	9.37	14.09
126.23	0.035	0.143	1.3	8.58	9.81	14.71

PROTECO LANDFILL
REACH "G" DRAINAGE CALCULATIONS

SLOPE = 5.3%, n=0.038

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
0.78	0.038	0.053	0.1	0.42	4.45	1.86
2.52	0.038	0.053	0.2	0.88	4.89	2.86
5.03	0.038	0.053	0.3	1.38	5.34	3.65
8.27	0.038	0.053	0.4	1.92	5.79	4.31
12.23	0.038	0.053	0.5	2.50	6.24	4.89
16.91	0.038	0.053	0.6	3.12	6.68	5.42
22.30	0.038	0.053	0.7	3.78	7.13	5.90
28.44	0.038	0.053	0.8	4.48	7.58	6.35
35.32	0.038	0.053	0.9	5.22	8.02	6.77
36.06	0.038	0.053	0.91	5.30	8.07	6.81
36.79	0.038	0.053	0.92	5.37	8.11	6.85
37.54	0.038	0.053	0.93	5.45	8.16	6.89
42.98	0.038	0.053	1	6.00	8.47	7.16
51.43	0.038	0.053	1.1	6.82	8.92	7.54
60.69	0.038	0.053	1.2	7.68	9.37	7.90
70.78	0.038	0.053	1.3	8.58	9.81	8.25

PROTECO LANDFILL
REACH "G" DRAINAGE CALCULATIONS

SLOPE = 14.3%, n=0.038

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
1.28	0.038	0.143	0.1	0.42	4.45	3.05
4.13	0.038	0.143	0.2	0.88	4.89	4.70
8.26	0.038	0.143	0.3	1.38	5.34	5.99
13.59	0.038	0.143	0.4	1.92	5.79	7.08
20.09	0.038	0.143	0.5	2.50	6.24	8.04
27.77	0.038	0.143	0.6	3.12	6.68	8.90
36.63	0.038	0.143	0.7	3.78	7.13	9.69
37.59	0.038	0.143	0.71	3.85	7.18	9.77
38.55	0.038	0.143	0.72	3.92	7.22	9.84
39.53	0.038	0.143	0.73	3.99	7.26	9.92
40.52	0.038	0.143	0.74	4.06	7.31	9.99
46.71	0.038	0.143	0.8	4.48	7.58	10.43
58.02	0.038	0.143	0.9	5.22	8.02	11.12
70.60	0.038	0.143	1	6.00	8.47	11.77
84.48	0.038	0.143	1.1	6.82	8.92	12.39
99.69	0.038	0.143	1.2	7.68	9.37	12.98
116.27	0.038	0.143	1.3	8.58	9.81	13.55



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page 17 of 29

Proj. No.	Client	Location	Subject
16139	PROTECO	Panekos, PR	Drainage Swales
Preparer's Initials	Date	Reviewer's Initials	Approver's Initials

Check Reach "G" spreadsheet for $s = 5.3\%$, $d = 0.9$, $n = 0.038$

$$A = 4(0.9) + 0.9(2(0.9))$$

$$A = 5.22 \text{ ft}^2$$

$$P = 4 + (2) \sqrt{(0.9)^2 + (2(0.9))^2}$$

$$P = 8.02 \text{ ft}$$

$$Q = 5.22 \left(\frac{1.49}{0.038}\right) \left(\frac{5.22}{8.02}\right)^{\frac{2}{3}} (0.053)^{\frac{1}{2}}$$

$$Q = 5.22 (39.21) (0.75) (0.23)$$

$$Q = 35.31 \text{ cfs } \underline{\text{OK}}$$

Check Reach "G" spreadsheet for $s = 14.3\%$, $d = 0.71$, $n = 0.038$

$$A = 4(0.71) + 0.71(2(0.71))$$

$$A = 2.84 + 1.01$$

$$A = 3.85 \text{ ft}^2$$

$$P = 4 + \sqrt{0.71^2 + (2(0.71))^2} (2)$$

$$P = 7.18$$

$$Q = 3.85 \left(\frac{1.49}{0.038}\right) \left(\frac{3.85}{7.18}\right)^{\frac{2}{3}} (0.143)^{\frac{1}{2}}$$

$$Q = 3.85 (39.21) (0.64) (0.38)$$

$$Q = 37.6 \text{ cfs } \underline{\text{OK}}$$



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

						Page <u>18</u> of <u>29</u>
Proj. No.	Client	Location	Subject			
16139	PROTECO	Ponceletas, P.R.	Preparer's Initials	JAL	Date 9/9/94	Reviewer's Initials MLP Date 9/21/94 Approver's Initials Date

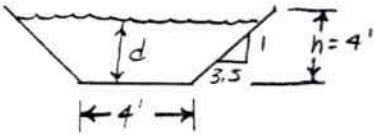
Reach "H" Drainage Swale

Check min. slope for capacity

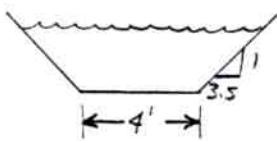
$$A = 4(d) + d(3.5d)$$

$$P = 4 + (2) \sqrt{d^2 + (3.5d)^2}$$

$$Q = 23.6 \text{ cfs}$$

From spreadsheet w/ $S = 14.3\%$,Flow depth $\approx 0.5'$ \therefore depth sufficient

$$\text{Min. } S = \frac{2'}{14'} = 14.3\%$$



$$\text{Max. } S = \frac{2'}{12'} = 16.7\%$$

Calculate velocity at max. slope for rip rap sizing

$$A = 4(d) + d(3.5d)$$

$$P = 4 + (2) \sqrt{d^2 + (3.5d)^2}$$

From spreadsheet w/ $S = 16.7\%$,Max velocity $\approx 8.8 \text{ fps}$ \therefore Use R-4 rip rap max. velocity = 9.0 fpsCheck Reach "H" spreadsheet for slope = 14.3%, $d = 0.5$

$$A = 4(0.5) + 0.5(3.5(0.5))$$

$$A = 2 + 0.88 = 2.88$$

$$P = 4 + (2) \sqrt{0.5^2 + (3.5(0.5))^2}$$

$$P = 4 + 3.64 = 7.64$$

PROTECO LANDFILL
REACH "H" DRAINAGE CALCULATIONS

SLOPE = 14.3%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
1.42	0.035	0.143	0.1	0.44	4.73	3.25
4.66	0.035	0.143	0.2	0.94	5.46	4.96
9.50	0.035	0.143	0.3	1.52	6.18	6.27
15.95	0.035	0.143	0.4	2.16	6.91	7.38
22.29	0.035	0.143	0.48	2.73	7.49	8.18
23.16	0.035	0.143	0.49	2.80	7.57	8.27
24.05	0.035	0.143	0.5	2.88	7.64	8.36
33.86	0.035	0.143	0.6	3.66	8.37	9.25
45.46	0.035	0.143	0.7	4.52	9.10	10.07
58.94	0.035	0.143	0.8	5.44	9.82	10.83
67.96	0.035	0.143	0.86	6.03	10.26	11.27
69.53	0.035	0.143	0.87	6.13	10.33	11.34
71.13	0.035	0.143	0.88	6.23	10.41	11.42
72.74	0.035	0.143	0.89	6.33	10.48	11.49
74.37	0.035	0.143	0.9	6.44	10.55	11.56
91.85	0.035	0.143	1	7.50	11.28	12.25
111.45	0.035	0.143	1.1	8.64	12.01	12.91
133.26	0.035	0.143	1.2	9.84	12.74	13.54
157.36	0.035	0.143	1.3	11.12	13.46	14.16

PROTECO LANDFILL
REACH "H" DRAINAGE CALCULATIONS

SLOPE = 16.7%

Flow (cfs)	n	Slope (%)	Flow Depth (ft)	Area (sq. ft.)	Wetted Perimeter (ft)	Velocity (fps)
1.53	0.035	0.167	0.1	0.44	4.73	3.52
5.03	0.035	0.167	0.2	0.94	5.46	5.36
10.27	0.035	0.167	0.3	1.52	6.18	6.78
17.24	0.035	0.167	0.4	2.16	6.91	7.98
20.52	0.035	0.167	0.44	2.44	7.20	8.42
21.38	0.035	0.167	0.45	2.51	7.28	8.52
22.27	0.035	0.167	0.46	2.58	7.35	8.63
23.17	0.035	0.167	0.47	2.65	7.42	8.73
24.09	0.035	0.167	0.48	2.73	7.49	8.84
25.03	0.035	0.167	0.49	2.80	7.57	8.94
25.99	0.035	0.167	0.5	2.88	7.64	9.04
36.59	0.035	0.167	0.6	3.66	8.37	10.00
49.13	0.035	0.167	0.7	4.52	9.10	10.88
63.69	0.035	0.167	0.8	5.44	9.82	11.71
73.44	0.035	0.167	0.86	6.03	10.26	12.18
75.14	0.035	0.167	0.87	6.13	10.33	12.26
76.86	0.035	0.167	0.88	6.23	10.41	12.34
78.61	0.035	0.167	0.89	6.33	10.48	12.41
80.37	0.035	0.167	0.9	6.44	10.55	12.49
99.26	0.035	0.167	1	7.50	11.28	13.23
120.44	0.035	0.167	1.1	8.64	12.01	13.95
144.01	0.035	0.167	1.2	9.84	12.74	14.64
170.06	0.035	0.167	1.3	11.12	13.46	15.30



OHM Corporation

COMPUTATION SHEET

Form No. 0048
 Midwest Tech. Servs.
 Rev. 08/89

Page 19 of 29

Proj. No. 16139	Client PROTECO	Location Ponceletas, P.R.	Subject Drainage Swales
Preparer's Initials JAL	Date 9/12/94	Reviewer's Initials MLP	Date 9/21/94

Check Reach "H" spreadsheet for slope = 16.7 %, d = 0.48

$$A = 4(d) + d(3.5d)$$

$$A = 4(0.48) + 0.48(3.5(0.48))$$

$$A = 2.73 \text{ ft}^2$$

$$P = 4 + (2) \sqrt{(0.48)^2 + (3.5(0.48))^2}$$

$$P = 7.49$$

$$Q = 2.73 \left(\frac{1.49}{0.035} \right) \left(\frac{2.73}{7.49} \right)^{2/3} (0.167)^{1/2}$$

$$Q = 2.73(42.57)(0.51)(0.41)$$

$$Q = 24.15 \text{ cfs } \underline{\text{OK}}$$

Reach "I" Drainage Swale

$$Q = Q_{\text{Reach F}} + Q_{\text{Reach G}} + Q_{\text{Area I}}$$

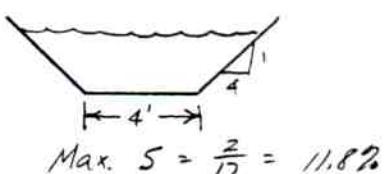
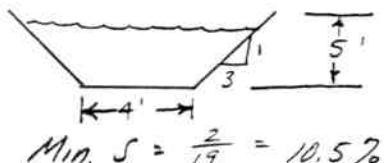
$$Q_{\text{Area I}} = CIA \quad C = 0.93 \quad (\text{See Page 1 of 5 of Drainage Calculations})$$

$$I = 5.25 \text{ "/hr.}$$

$$Q_{\text{Area I}} = (0.43)(5.25)(0.12) \quad A = 0.12 \text{ Acres}$$

$$Q_{\text{Area I}} = 0.3 \text{ cfs}$$

$$Q = 18 \text{ cfs} + 37.4 \text{ cfs} + 0.3 \text{ cfs} = 55.7 \text{ cfs}$$





OHM Corporation

COMPUTATION SHEET

Form No. 0048
Midwest Tech. Servs.
Rev. 08/89

Page 20 of 29

Proj. No. 16139	Client PROTECO	Location Penobscot, P.R.	Subject Drainage Swales
Preparer's Initials JAL	Date 9/12/94	Reviewer's Initials MLP	Date 9/21/94

Check Min. Slope for capacity

$$A = 4(d) + d(3d)$$

$$P = 4 + (2) \sqrt{d^2 + (3d)^2}$$

From 10.5% slope spreadsheet,

Flow depth = 0.86', channel depth = 5' OK

Calculate velocity at max. slope for rip rap sizing

$$A = 4(d) + d(4d)$$

$$P = 4 + (2) \sqrt{d^2 + (4d)^2}$$

From 11.6% slope spreadsheet,

Max velocity = 9.6 fps

∴ Use R-5 rip rap

Check Reach "I" spreadsheet for $S = 10.5\%$, $n = 0.038$, $d = 0.9$

$$A = 4(0.9) + 0.9(3(0.9))$$

$$A = 3.6 + 2.43 = 6.03 \text{ ft}^2$$

$$P = 4 + (2) \sqrt{(0.9)^2 + (3(0.9))^2}$$

$$P = 4 + 5.69 = 9.69 \text{ ft}^2$$